Instruction Sheet

MS-24

Heating, Cooling, and Ventilating
TL-8, June 15, 1987

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Quality Survey for MS Handbook
MS - ______________

1. The MS Handbook contains the information required to perform maintenance on the equipment.

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Comments: ______________________________

____

____

2. The drawings in the MS Handbook accurately represent the equipment.

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Comments: ______________________________

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3. The MS Handbook meets the required needs of the Maintenance Technician.

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Comments: ______________________________

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4. The MS Parts Information meets the required needs of the Maintenance Technician.

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
☐	☐	☐	☐	☐

Comments: ______________________________

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5. Do you have any suggestions for things to be added and/or removed from the MS Handbook to make it easier to use?

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Maintenance Handbook MS-24
Heating, Cooling, and Ventilating

Transmittal Letter 8
June 15, 1987

A. Explanation

This is a complete revision of Maintenance Handbook MS-24, *Heating, Cooling, and Ventilating.*

B. Distribution

1. **Initial.** Copies of this complete issue are being distributed to all facilities.
2. **Additional Copies.** Order additional copies by submitting Form 7380, *Supply Center Requisition*, to the Supply Center, specifying HBKMS24.

C. Rescissions

All previous issues of Maintenance Handbook MS-24, Transmittal Letters 1-7, are rescinded and should be discarded.

D. Comments and Questions

Suggestions for improving this handbook are solicited from all sources. Anyone wishing to make such recommendations should use the preaddressed postcards at the back of this handbook.

E. Effective Date

These instructions are effective upon receipt.

Charles E. Bravo

for . *James C. Wilson*
Director
Office of Maintenance Management
Engineering & Technical Support Department

UNITED STATES POSTAL SERVICE™

Heating, Cooling, and Ventilating

Maintenance Handbook
MS-24

TL-8, June 15, 1987

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List of Effective Pages	
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Correction or Change	Purpose of Correction or Change	Entered By	Date

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CHAPTER 1

INTRODUCTION

110 GENERAL MAINTENANCE REQUIREMENTS

111 BASIC REQUIREMENTS

The proper operation and maintenance of building heating, cooling, and ventilating systems requires a careful weighing of many factors. Responsible operation and maintenance consists of providing the following at the lowest possible cost:

a. An environmentally acceptable atmosphere for employees

b. Operation of equipment within guidelines established by the USPS and the equipment manufacturer

c. Maintenance of the equipment to provide maximum safety to the operation, postal employees, and the general public

d. Operation and maintenance to provide functional efficiency and extended service life

112 OTHER FACTORS

Inherent in the above responsibility are certain decisions based on cost-effectiveness for personnel authorizations, training requests, repair and improvement requests, maintenance equipment purchases, and contracting provisions. Effective maintenance management requires proper tools, adequate supervision, timely inspection, meaningful information, and technical competence. It also requires administering through open lines of communications at all levels and the use of good judgment, knowledge, and common sense.

120 SCOPE

This handbook applies to USPS personnel engaged in the operation and maintenance of facility heating, cooling, and ventilation systems. It prescribes the policies, procedures, and practices governing the operation of systems installed in USPS buildings and in leased space where the USPS has maintenance responsibility.

130 SAFETY

The procedures prescribed in this handbook place special emphasis on safe work practice and maintaining a safe environment for building occupants and the public. The provisions set forth by HBK EL-801, Supervisor's Safety Handbook, HBK EL-803, Maintenance Employee's Guide to Safety, and the specific manufacturer's operating and maintenance manuals or bulletins apply to all work and maintenance. All employees must be properly trained in these procedures.

140 ADDITIONAL REFERENCE MATERIAL

Maintenance bulletins prepared and distributed by the Office of Maintenance Management, Engineering and Technical Support Department, Headquarters, may contain additional instructions for supplementing or modifying procedures and practices prescribed in this handbook. Additional discussion of material presented in the handbook is also found in the following handbooks:

a. HBK MS-1, Operation and Maintenance of Real Property, (Section 10)

b. HBK MS-42, Air and Water Balancing

c. HBK MS-49, Energy Conservation and Maintenance Contingency Planning in Large Postal Facilities

150 BASIC SKILLS TRAINING

The United States Postal Service must protect the health and safety of its personnel as well as the capital investment in facility heating, cooling, and ventilating systems. Therefore, personnel should not be allowed to operate, repair, maintain, or modify these systems unless they have been provided the training and/or supervision deemed appropriate by facility management for the tasks assigned. Although this handbook provides an understanding of postal policy and equipment operation, it is not suitable for development of employee skills from a level of first introduction to heating, cooling, and ventilating principles. To obtain a basic understanding of the concepts presented in this handbook, use the following self-study courses available from the local Postal Employee Development Center (PEDC):

a. 56510-00, "Maintenance Safety Awareness Training"

b. 56503-00, "Introduction to Refrigeration and Air-Conditioning"

NOTE

Maintenance supervisors at each site should be familiar with the content of these courses and should utilize the courses as the foundation of an operations and maintenance training plan suited to the particular requirements of each facility.

160 SYSTEMS TRAINING

Before performing full operational maintenance, personnel must be provided the training deemed appropriate by local maintenance management with respect to the functions of individual employee assignments. The following courses, provided by the USPS Technical Training Center, Norman, Oklahoma, may be necessary to ensure fully developed operating and maintenance skills:

a. 55687-02, "Industrial Electrical Service"

b. 55686-00, "Environmental Control I (HVAC)"

c. 55689-21, "Environmental Control II (Honeywell)"

d. 55689-22, "Environmental Control II (Johnson)"

e. 55689-23, "Environmental Control II (Barber-Colman)"

f. 55689-24, "Environmental Control II (Powers)"

g. 55689-25, "Environmental Control II (Robertshaw)"

h. 55689-05, "Environmental Control III (HVAC Heating)"

i. 55689-08, "Environmental Control IV (Advanced Air-Conditioning)"

j. 55689-12, "General Monitoring System (GMS) II Operators Training"

k. 55689-13, "General Monitoring System (GMS) II Maintenance Training"

NOTE

Maintenance supervisors at each site should be familiar with the content of these courses and should use the courses as a basic foundation for an operations and maintenance training plan suited to the particular requirements of each facility.

170 SUPERVISORY TRAINING

USPS supervisory personnel responsible for building heating, cooling, and ventilating systems should be provided the opportunity to attend the USPS Technical Training Center course No. 55689-07, "Environmental Control V." This training is necessary to ensure that building systems are operated in a manner consistent with good energy conservation practices.

180 NONPOSTAL TRAINING

Because of the wide diversity of manufacturers and types of equipment installed in thousands of postal facilities, the USPS recognizes that it cannot provide indepth technical training for every specific make and model of building system equipment. To provide suitable equipment training, it may be necessary to contract with commercial vendors for training designed to develop operations and maintenance proficiency for Postal Service personnel. The procedures necessary to obtain approval for this type of training are contained in Chapter 7 of the Employee and Labor Relations Manual (ELM), Part 740.

CHAPTER 2

SELF-CONTAINED HVAC UNITS

210 DEFINITIONS

A self-contained heating, ventilating, or air-conditioning (HVAC) unit incorporates some or all of the components of an air-conditioning or heating system, except possibly the duct work and water piping. In most installations, the air is discharged directly into the room through a grille. Less frequently, the unit is attached to duct work for distribution of air to remote parts of the room.

220 WINDOW AIR-CONDITIONING UNITS

221 SIZE AND APPLICATION

221.1 Capacity

To establish a uniform method of measuring capacity, most manufacturers comply with standards to rate and test their units in terms of British Thermal Units per hour (Btu/hr). By this method, various makes and models of air-conditioners are rated according to the number of Btus of heat they will remove from a room in a given period of time. For example, a one-ton air-conditioner will remove 12,000 Btu/hr. Window unit capacities usually range from 4,200-24,000 Btu/hr.

221.2 Operating Efficiency

.21 **Air-Conditioners (A/C).** The efficiency of self-contained units is expressed as an Energy Efficiency Ratio (EER). The EER is obtained by dividing the unit rating in Btu/hr by the electrical power input.

$$EER = \frac{\text{Btu/hr output}}{\text{watt input}}$$

For most units, an EER of 9 or 10 would be considered good; an EER of 5 or 6 would be considered very poor. Some window units have been built with EERs as high as 12 to 14.

.22 **Heat Pumps.** The efficiency of a heat pump (an A/C unit with the condenser and evaporator reversed) is referred to as Coefficient of Performance (COP). The COP is the ratio of the heat out to the electrical energy in.

$$COP = \frac{\text{heat out (Btu)}}{\text{electrical energy in (Btu)}}$$

The COP will go down with the outside temperature. A typical COP rating would be like this:

Outdoor Temp.	COP
65	2-3/4
40	2-1/2
30	2-1/4
10	1-3/4
-10	1-1/3
-20	1-1/10

Thus, the heat pump can operate much more efficiently than electrical resistance heating because electrical resistance heating has a COP of 1.0 (assuming no losses in the wiring to the heater).

221.3 Installation

Windows are not necessary to install these units. They may be installed in transoms or directly in outside walls (commonly called a through-the-wall installation). The unit must have access to outside air for ventilation and exhaust purposes, and for the air-cooled condenser.

221.4 Thermostats

Most room coolers are equipped with thermostats that maintain, within reasonable limits, a fixed dry-bulb temperature and, indirectly, an area's moisture content.

222 COMPONENTS

222.1 General

In construction and operating principles, the window unit is a small and simplified version of a system designed to service a complete floor or building. The basic components of a window unit (as shown in Figures 2-1 and 2-2) are described in the following sections.

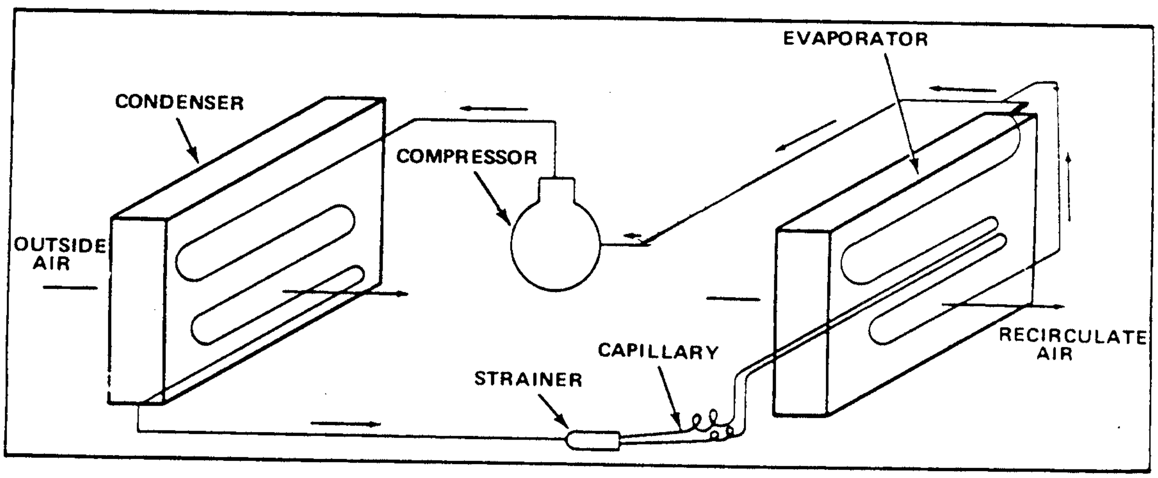


Figure 2-1
REFRIGERANT CYCLE OF A ROOM AIR-CONDITIONER

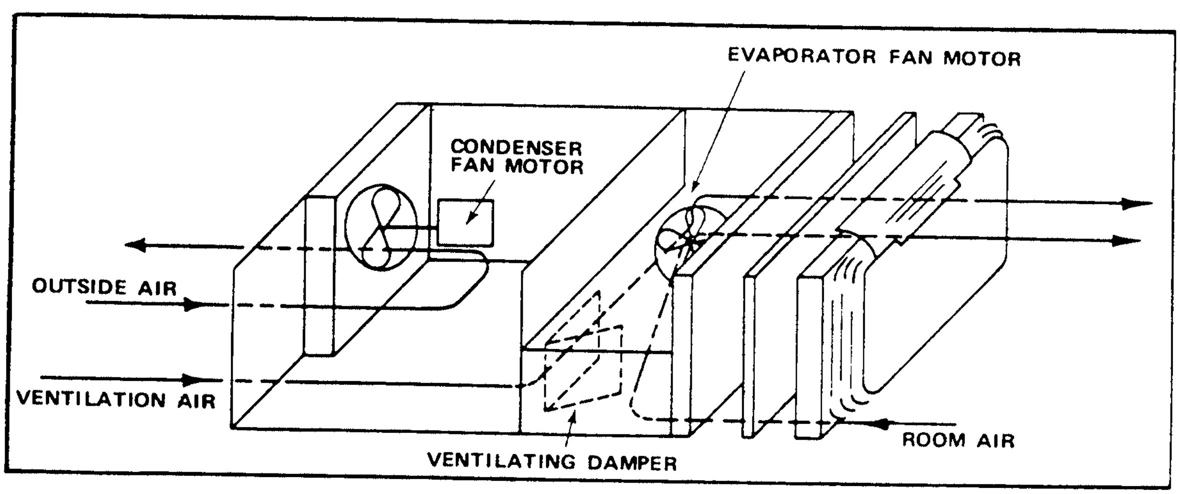


Figure 2-2
AIR HANDLING COMPONENTS OF A ROOM AIR-CONDITIONER

222.2 Compressor

In a window unit, the compressor is usually a hermetic single cylinder, reciprocating or rotary type.

222.3 Condenser

The condenser coils are cooled by air blown across the coils by a condenser fan. Water is condensed from the humid room air that comes in contact with the evaporator coils. The water is collected in a pan at the bottom of the unit and is usually directed to the condenser fan. The fan then picks it up in the form of droplets and mist which evaporates on the condenser, thereby removing heat from the condenser.

222.4 Evaporator

Because of the usually limited space available for window units, a finned-tube evaporator is used to transfer more heat per foot of pipe. The space between the fins may vary from one unit to another according to the intended application.

222.5 Capillary Tube

On small equipment like a window unit, the type of metering device generally used is a capillary tube. Because of its small inside diameter, it creates the pressure drop necessary for evaporation of the refrigerant. To create the desired pressure drop, the capillary tube is cut to a definite length for a particular size unit.

222.6 Fan Units

Room air is circulated by a fan that blows the air across the evaporator coils. The fan may be either a forward-curved blower wheel, or an axial- or radial-flow fan blade. In general, blower wheels are used to move small to moderate amounts of air in a high-resistance system, while fan blades are used to move moderate to high air volumes in low-resistance applications.

223 CONTROLS AND OPERATION

223.1 Controls

Window units usually have two primary controls. The first is a thermostat. The remote bulb element of the thermostat responds to temperature changes and either starts or stops the unit, according to a predetermined temperature setting. The second primary control sets the speed of the evaporator fan motor. The unit usually operates at more than one speed within the range established by the control, which is manually operated. Other controls adjust the discharge louvers to direct the flow of air in the desired direction.

223.2 Operation

A window-mounted unit is not adjusted properly when cold blasts of air are felt. Better circulation results if the unit's adjustable louvers are turned so the cold air is blown upward. After rising to the ceiling, the air will flow gently down toward the opposite side of the room, and no streams of cold air are directed at people. If more than the usual number of people are expected to occupy the room, the room should be cooled ahead of time. On high speed, the temperature of the room can be lowered rapidly, but noise is often produced.

224 MAINTENANCE GUIDELINES

224.1 Blades

Figure 2-3 shows a typical window unit. Keep fan blades and finned tubes clean; do not allow foreign material to build up on them. When cleaning the blades, do not use abrasives that will wear surfaces. If solids form on blades, scrape them off with a putty knife, then clean the blades with detergent and a sponge. Do not bend, twist, or warp the blades, and do not allow blades to catch

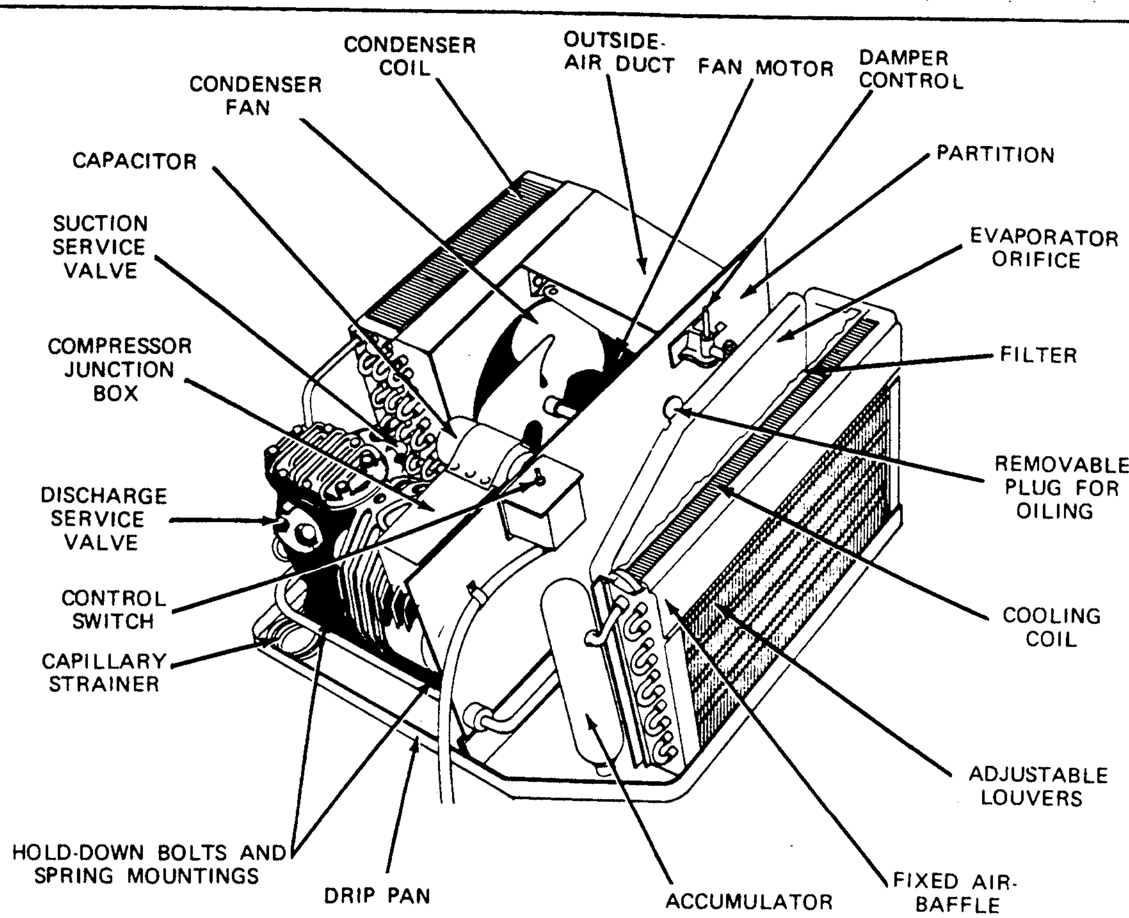


Figure 2-3

WINDOW MOUNTED AIR-CONDITIONER WITH CABINET REMOVED AND SHOWING MAINTENANCE POINTS

or bind in the housing or shroud. Excessive vibration damages the fan shaft and bearing. Vibration is caused by a bent shaft, imbalance in the fan, loose anchor bolts, or loose setscrews on the fan hub.

224.2 Motors

Keep motors clean and lubricate them according to the manufacturer's recommendations. Check for loose electrical connections, switches, and terminals.

224.3 Filters

Check filters as frequently as necessary to prevent excessive dust and lint collecting, which reduces the unit's efficiency. Under no circumstances may air-conditioners be operated without filters.

224.4 Inspections

Make periodic checks to determine the need for tightening or replacing broken parts or repainting surfaces. Keep controls in operable condition.

224.5 Other Procedures

In the maintenance of these units, observe the following:

a. Do not tamper with the hermetically-sealed refrigeration equipment, factory-calibrated automatic temperature controls, or other devices covered by warranties.

b. Never mix different refrigerants in the same system. Operating characteristics of refrigerants are different and use of the wrong refrigerant may cause equipment damage.

c. The refrigerant should not be allowed to become contaminated with moisture.

d. Maintenance personnel must warn occupants not to operate an air-conditioner when the refrigerant supply in the system is very low. One indication of low supply is an evaporator covered with frost. A sample preventive maintenance checklist for these type units is contained in Exhibit 2-1 (Appendix C).

230 FLOOR-MOUNTED UNITS

231 PACKAGE AIR-CONDITIONING SYSTEMS

These units range in size from 2 to 30 tons and are sometimes referred to as "package" units. They may be used with "free throw"; i.e., without ducts, as shown in Figure 2-4, or with duct work as shown in Figure 2-5.

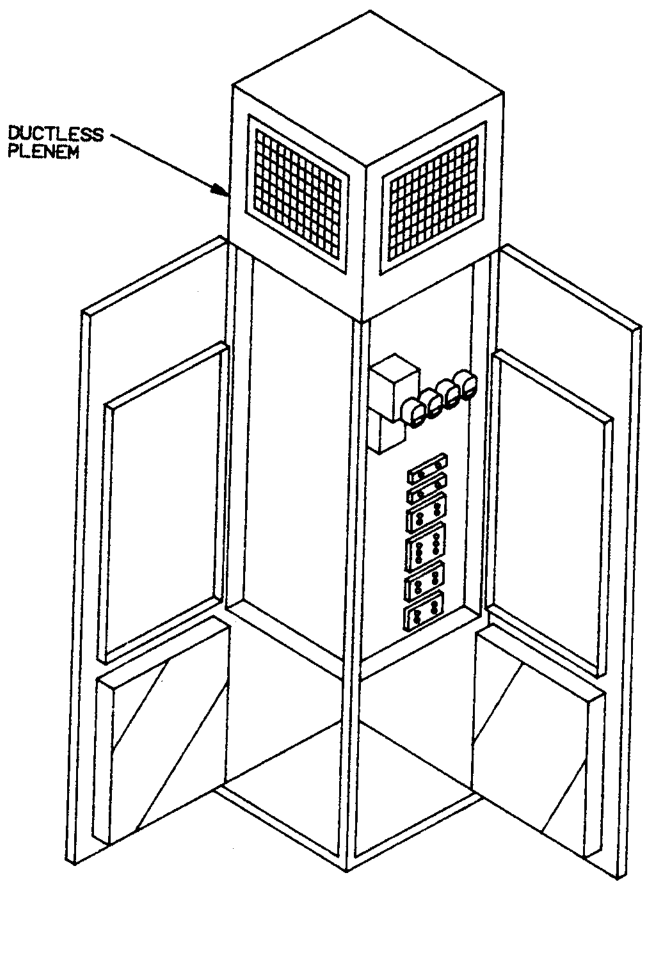


Figure 2-4
"FREE THROW" PACKAGE AIR-CONDITIONING SYSTEM

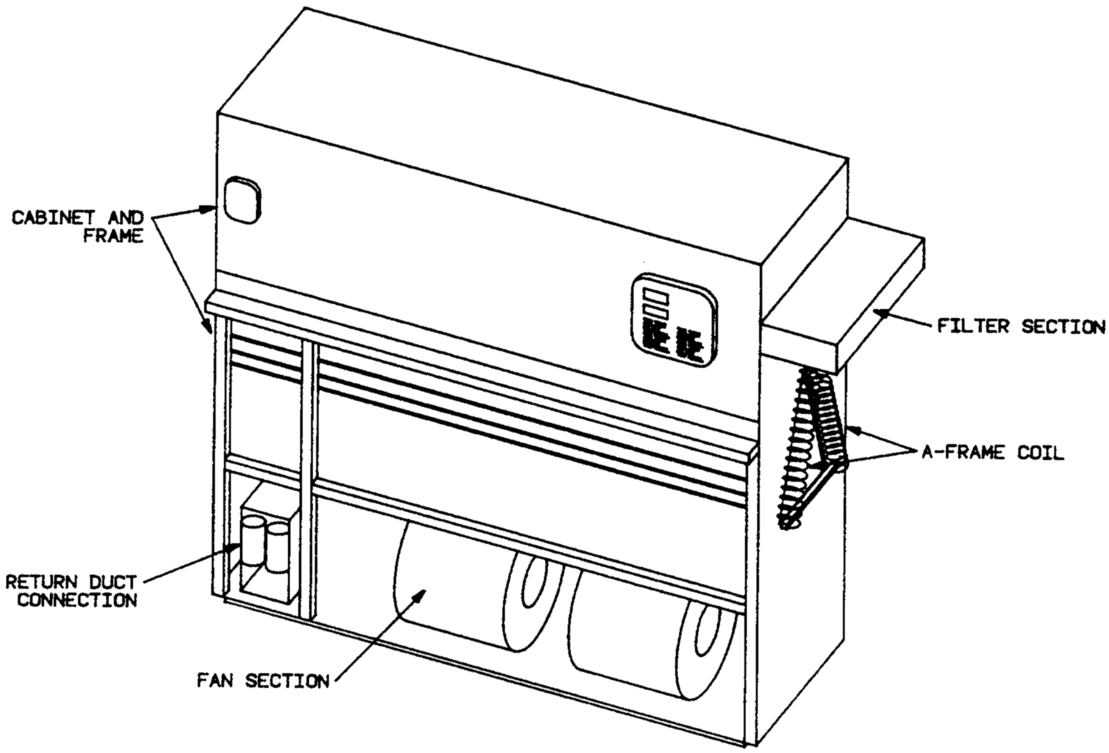


Figure 2-5

PACKAGE AIR-CONDITIONING SYSTEM WITH DUCT WORK

232 COMPONENTS

232.1 General

Like window units, these larger units contain the complete system of refrigeration components.

232.2 Compressor

Floor-mounted units, in general, use hermetically-sealed, reciprocating compressors. Compressors in the larger capacity units may be the hermetic serviceable, multiple-cylinder type.

232.3 Condenser

In floor-mounted units, chilled-water, water-cooled, air-cooled, or glycol-cooled condensers are used. Some may be equipped with remote air-cooled condensers. See Figure 2-6 for representative installations.

232.4 Evaporator

The floor unit is built with a direct expansion evaporator.

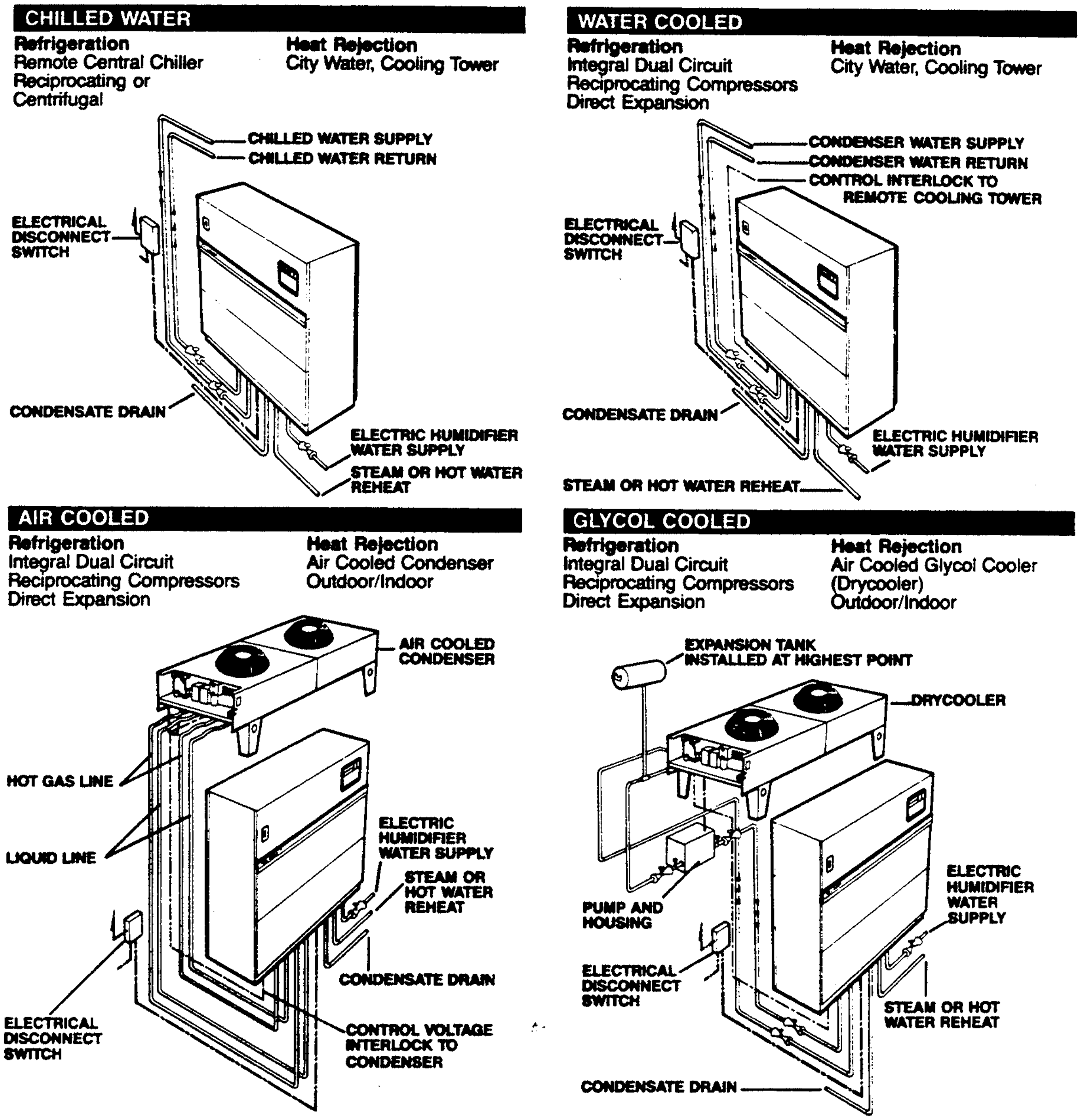


Figure 2-6

REPRESENTATIVE INSTALLATIONS FOR CONDENSERS

232.5 Metering Device

The refrigerant control in a floor unit is generally a thermostatic expansion valve of the distributor tube type. This valve contains a distributing tube or manifold in the body of the valve. Tubes are connected from the manifold to each coil in the evaporator, reducing the pressure drop across the large evaporating coil.

232.6 Fan Unit

Airflow in floor units usually involves higher static pressures than in window units, in addition to duct friction. With the added static pressure and required low noise level, these units are normally equipped with two centrifugal fans; one fan for the evaporator and one for the condenser where an air-cooled condenser is installed.

232.7 Humidity Controls

Depending on the site criteria, some floor units also provide control of humidity by either removing moisture from the air (dehumidification) or adding moisture (humidification). Control of humidity is especially common in computer room air-conditioning units, where, to prevent static discharge problems, the relative humidity is generally maintained between 40 and 60 percent. To dehumidify, the compressor must work beyond the point of removing sensible heat. The result is a room temperature that is uncomfortably low. After the moisture has been removed at the evaporator, the temperature of the excessively cold air is then raised to the desired level by a reheat coil. The reheat coil is supplied with hot water or steam from an independent source or from the water-cooled condenser. To humidify, water is fed into a holding trough in the air-conditioning unit. This water is then heated via lamps or heating elements until the water temperature approaches 120 to 160 °F. At this point, grains of pure moisture are released into the airstream passing over the trough.

233 MAINTENANCE GUIDELINES

233.1 Filters

Filters are usually the most neglected item in an environmental control system. To maintain efficient operation, they should be checked and changed as required. If replacement of air filters can be done from either end by opening the end doors, it is recommended that filters be changed from the compressor side of the unit (see Figure 2-5). After replacing filters, test the operation of the filter clog switch.

CAUTION

Before opening unit, be sure power is turned off.

233.2 Humidifier

During the course of normal humidifier operation, deposits of mineral solids collect on the sides and bottom of the humidifier pan. The pan should be cleaned out periodically to ensure efficient humidifier operation. Each city and locality has different water characteristics, making it difficult to establish any definite time intervals between cleanings.

CAUTION

Before removing pan, be sure power to unit is disconnected and the water temperature in the humidifier pan is not hotter than lukewarm. <u>IMPORTANT</u>: Do not touch the humidifier lamps with your bare hands; any oily deposits (fingerprints) will severely shorten bulb life. Always use clean cotton gloves.

233.3 Blower Package

.31 Inspection. Periodic checks of the blower package include inspection of belts, motor mounts, fan bearings, and impellers.

.32 Fan Impellers and Bearings. Fan impellers should be periodically inspected and any debris removed. Check to see if they are tightly mounted on the fan shaft. Rotate the impellers and make sure they do not rub against the fan housing.

.33 Belts. Drive belts should be checked for the proper tension and signs of wear. The current draw of the motor should be checked to see if it is within tolerance. Belts that are too tight can cause excessive bearing wear. With units using more than one V-belt in a single drive, power "band" belts (dual belts joined by a single carcass across the widest part) should be considered for installation because they provide a perfectly matched drive.

NOTE

After adjusting or changing belts, always ensure that motor mounts are tight, as loose mounts produce vibration and may damage the unit.

233.4 Electric Panel

The electric panel should be inspected for any loose electrical connections.

WARNING

Be sure that power to the unit is shut down before attempting to tighten any fittings or connections.

233.5 Refrigeration System

.51 Inspections. The components of the refrigeration system should be inspected for proper function and signs of wear. Since, in most cases, evidence of malfunction is present prior to component failure, periodic inspections are a major factor in the prevention of most system failures.

.52 Compressor Oil Level. To view the oil level, use the glass "bull's-eye" (if provided) on the compressor. Normally, the oil level should be 1/2 to 3/4 from the bottom of the sight glass. However, this level may vary during operation due to the action of the moving parts. When idle, the oil level may be higher due to the absorption of refrigerant. After a compressor has been idle for an extended length of time, foaming will generally appear when the compressor again restarts. In order to accurately check the oil level, it is necessary to operate the compressor 5 to 10 minutes before viewing the oil level. Refrigeration oil does not deteriorate with normal usage and need not be changed unless discolored or acidic. Periodically inspect the compressor compartment for signs of oil leakage. If a leak is present, it must be corrected and the oil returned to its proper level. It is recommended that oil be taken from sealed containers opened at the time of use. Oil exposed to the air absorbs moisture.

.53 Refrigerant Lines. Refrigerant lines must be properly supported and must not vibrate against ceilings, floors, or unit frame. Inspect capillary and equalizer lines from the expansion valve and support as necessary.

Some liquid lines have a sight glass that indicates liquid-refrigerant flow and the presence of moisture. Bubbles in the sight glass indicate a shortage of refrigerant or a restriction in the liquid line. The moisture indicator changes from green to yellow when moisture is present in the system. (See Figure 2-7.)

.54 **Suction Pressure.** Suction pressure varies with load conditions. If suction pressure falls below the cutout setting, the low-pressure switch shuts the compressor down. High suction pressure reduces the ability of the refrigerant to cool compressor components and can result in compressor damage.

.55 **Superheat.** Superheat refers to the difference in temperature between the vapor in the low side and in the sensing bulb and can be adjusted by the Thermostatic Expansion Value (TEV/TXV). To determine superheat:

a. Measure the temperature of the suction line at the point where the TEV bulb is clamped.

b. Obtain the gauge pressure at the compressor suction valve.

c. Add the estimated pressure drop between bulb location and suction valve.

d. Convert the sum of the two pressures to the equivalent temperature.

e. Subtract this temperature from the actual suction line temperature; the difference is superheat.

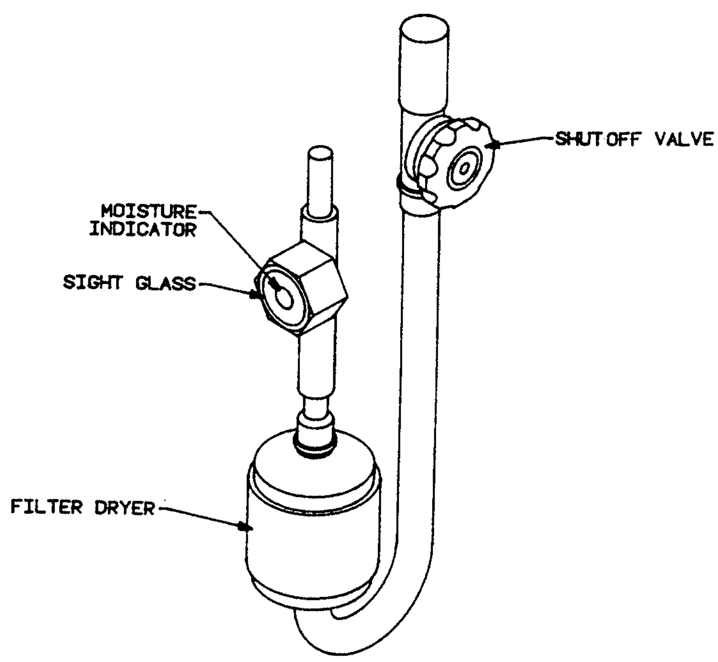


Figure 2-7
LIQUID-LINE SIGHT GLASS

.56 Discharge Pressure. Discharge pressure is increased or decreased by either load conditions or condenser efficiency. The high-pressure switch shuts the compressor down at its cutout setting.

.57 Hot Gas Bypass Valve Operation. The hot gas bypass is inserted between the compressor discharge line and the leaving side of the expansion valve through the side outlet distributor. A system, normally operating when the evaporator is under full load, will maintain enough pressure on the leaving side of the hot gas valve to keep the valve port closed. Should the load on the evaporator decrease to the point where the coil is below the setting desired, the pressure on the discharge of the hot gas bypass will put pressure on the diaphragm, overcoming the spring pressure on the seat, and allowing some hot gas to mix with the normal liquid discharge of the expansion valve. This raises the evaporator pressure, and reduces the cooling capacity of the unit to match the load.

.58 Thermostatic Expansion Valve Operation. The thermostatic-expansion valve keeps the evaporator supplied with enough refrigerant to satisfy load conditions. It does not control compressor operation. Proper valve operation can be determined by measuring superheat. If too little refrigerant is being fed to the evaporator, the superheat will be high; if too much refrigerant is being supplied, the superheat will be low.

.59 Crankcase Heater. The crankcase heater should be turned on at least 24 hours prior to operation of the unit.

NOTE

Consult manufacturer's instructions for proper superheat value. When making adjustments, make no more than one turn of the stem at a time. As long as 30 minutes may be required for the new balance to take place.

233.6 Air-Cooled Condenser

Restricted airflow through the condenser coil reduces the operating efficiency of the unit, resulting in high compressor head pressure and loss of cooling. Clean the condenser coil of all debris that inhibits airflow. This can be done with compressed air or a commercial coil cleaner. Check for bent or damaged coil fins and repair as necessary. In winter, do not permit snow to accumulate around the sides or underneath the condenser of running units. Check all refrigerant lines and capillaries for vibration isolation and support as necessary. Visually inspect all refrigerant lines for signs of oil leaks.

233.7 Water/Glycol-Cooled Condensers

Each water- or glycol-cooled module has a shell and tube condenser consisting of a shell, removable heads, gaskets, and cleanable copper tubes. It may be necessary to clean the copper tubing periodically to remove any scale or slime that could collect. (Periods between cleanings will vary with local water conditions.) As deposits build up, a cleaning tool, available at any refrigeration supply house, should be used to clean the heat exchanger tubes.

233.8 Glycol Solution Maintenance

Since the rate of inhibitor depletion depends on local water conditions, it is difficult to establish a specific schedule of inhibitor maintenance. Analysis of water samples at the time of installation and every 6 months thereafter helps to establish a pattern of depletion. A visual inspection of the solution and filter residue is often helpful in judging whether or not active corrosion is occurring. The complexity of water-caused problems and their correction makes it important to obtain the advice of a water-treatment specialist and to follow a regularly scheduled maintenance program. It is important to note that the improper use of water-treatment chemicals can result in problems more serious than using no chemicals at all.

NOTE

> See Subchapter 470 for a discussion of the use of glycol in chilled-water systems.

233.9 Compressor Failure

.91 **General.** If a compressor motor burns out, the stator wiring insulation decomposes, forming carbon, water, and acid. Not only must the compressor be replaced, but the entire refrigeration system must be cleaned of the harmful contaminants left by the burnout. Successive burnouts of the same system can usually be attributed to improper system cleaning. See the manufacturer's instructions for cleanout procedures. Before proceeding with a suspected burnout, a preliminary check of all electrical components should be made and all fuses and the Hi-Lo pressure switch operation should be checked.

.92 **Electrical Failure.** An electrical failure of the compressor is indicated by the distinct pungent odor of refrigerant being released through the service port. If a severe burnout has occurred, the oil will be black and acidic.

.93 **Mechanical Failure.** If the motor attempts to run, and no odor of burned gas is released at the service port, a mechanical failure is indicated. A sample preventive maintenance checklist for package air-conditioners is contained in Exhibit 2-2 (Appendix C). See Table 2-1, "Troubleshooting Guidelines for Self-Contained Air-Conditioners."

240 HEAT PUMPS

241 GENERAL

Heat pumps are designed to capture latent heat from ambient air through the use of refrigeration principles. For cooling, the heat pump operates in the same manner as a conventional packaged air-conditioner. For heating, the flow of refrigerant is reversed. (See Figure 2-8 for an illustration of a heat pump heating circuit.) The heating process starts with refrigerant circulating through the outdoor coil in a low-temperature low-pressure state. Since the refrigerant is much colder than the outside coil temperature, the refrigerant gains heat and changes into a hot gas. The refrigerant gas is then fed into the compressor which raises the gas temperature and pressure, and forces it to the indoor coil. When the hot refrigerant gas passes through the indoor coil, it is cooled by the lower temperature airflow surrounding the coil. When the gas cools, it condenses and returns to a liquid state completing the heat transfer at the indoor coil. After exiting the indoor coil, the liquid refrigerant passes through the expansion valve or capillary tube which transfers the refrigerant back to a low-pressure state. In addition to the heating cycle, a heat pump has two other cycles, cooling and defrost. During the cooling cycle, a four-way valve redirects refrigerant flow and, in conjunction with check valves installed

TABLE 2-1

TROUBLESHOOTING GUIDE FOR SELF-CONTAINED AIR-CONDITIONERS

COMPLAINT	CAUSE	POSSIBLE REMEDY
A. Open Type Compressor		
1. Electric motor will not start.	a. Power failure	a. Check circuit for power source.
	b. Compressor stuck	b. Locate cause and repair.
	c. Belt too tight	c. Adjust belt tension.
	d. Manual reset in starter open	d. Determine cause of overload and repair. Reset overload cutout.
	e. Thermostat setting too high	e. Lower thermostat setting.
	f. Low voltage	f. Check with voltmeter, then call power company.
	g. Burned-out motor	g. Repair or replace.
	h. Frozen compressor (caused by locked or damaged mechanism)	h. Remove and repair compressor.
2. Unit cycles on and off.	a. Intermittent power interruption	a. Tighten connections or replace defective power supply parts.
	b. High-pressure cutout defective	b. Replace high-pressure cutout.
	c. High-pressure cutout set too low Overload opens after having been reset	c. Raise cutout pressure. Check voltage and current drawn.
	d. Leaky liquid-line solenoid valve	d. Repair or replace.
	e. Dirty or iced evaporator	e. Clean or defrost evaporator. Check filters and fan drive.
	f. Overcharge of refrigerant or noncondensible gas	f. Remove excess refrigerant or purge noncondensible gas.
	g. Lack of refrigerant	g. Repair refrigerant leak and recharge.
	h. Restricted liquid-line strainer	h. Clean strainer.
	i. Faulty motor	i. Repair or replace faulty motor.
3. Coil frosts.	a. Filters dirty	a. Clean filters.
	b. Not enough air over coil	b. Clean or remove restriction from supply or return ducts or grilles.
	c. Defective expansion valve	c. Replace valve.
4. Unit runs but will not cool.	a. Unit not fully charged	a. Recharge slightly; check for leaks in the refrigerant circuit; then fully charge.
	b. Leaky suction valve or discharge valve	b. Remove compressor cylinder head and clean or replace valve plate.
	c. Expansion valve not set correctly	c. Adjust expansion valve.
	d. Strainer clogged	d. Remove, clean, and replace strainer.
	e. Air in refrigerant circuit	e. Purge unit of air. Clean orifice and install silica gel drier.
	f. Flash gas in liquid line	f. Add refrigerant.

TABLE 2-1 (Continued)

TROUBLESHOOTING GUIDE FOR SELF-CONTAINED AIR-CONDITIONERS

COMPLAINT	CAUSE	POSSIBLE REMEDY
5. No air blows from supply grille.	a. Ice or dirt on evaporator b. Blower belt broken or loose c. Blower bearing frozen	a. Clean coil or defrost. b. Adjust belt tension or replace belt. c. Repair or replace bearing and lubricate as directed.
6. Discharge pressure is too high.	a. Improper operation of condenser b. Air in system c. Overcharge of refrigerant	a. Correct air flow. Clean coil surface. b. Purge. c. Remove excess or purge.
7. Discharge pressure is too low.	a. Lack of refrigerant b. Broken or leaky compressor discharge valves	a. Repair leak and charge. b. Remove head, examine valves, and replace those found to be operating improperly.
8. Suction pressure is too high.	a. Overfeeding of expansion valve	a. Regulate superheat setting expansion valve and check to see that remote bulb is properly attached to suction line.
	b. Expansion valve stuck in open position c. Broken section valve in compressor	b. Repair or replace valve. c. Remove head, examine valves, and replace those found to be inoperative.
9. Suction pressure is too low.	a. Lack of refrigerant b. Clogged liquid-line strainer c. Expansion-valve power assembly has lost charge	a. Repair leak and charge. b. Clean strainer. c. Replace expansion-valve power assembly.
	d. Obstructed expansion valve e. Contacts on control thermostat stuck on closed position	d. Clean valve and replace if necessary. e. Repair thermostat or replace if necessary.
B. Hermetic Motor-Compressor Combination		
10. Compressor runs continuously (good refrigeration effect).	Air over condenser restricted	Remove restriction or provide for more air circulation over the condenser.
11. Compressor runs continuously (unit is too cold).	a. Thermostatic switch contacts badly burned b. Thermostatic switch bulb loose c. Thermostatic switch improperly adjusted	a. Replace thermostatic switch. b. Secure bulb in place. c. Readjust thermostatic switch.

TABLE 2-1 (Continued)

TROUBLESHOOTING GUIDE FOR SELF-CONTAINED AIR-CONDITIONERS

COMPLAINT	CAUSE	POSSIBLE REMEDY
12. Compressor runs continuously (little refrigeration effect).	a. Extremely dirty condenser b. No air ciculating over condenser c. Ambient temperature too high d. Load too great	a. Clean condenser. b. Provide air circulation. c. Provide ventilation or move to a cooler location. d. Analyze load.
13. Compressor runs continuously (no refrigeration).	a. Restriction that prevents the refrigerant from entering the evaporator. (Usually indicated by a slight refrigeration effect at the point of point of restriction.) b. Compressor not pumping. (Indicated by a cool discharge line and hot compressor housing; wattage generally low.) c. Short of refrigerant	a. Locate the possible points of restriction, and try jarring with a plastic hammer, or heating to a temperature of about 100 °F. If the restriction does not open, replace the unit. b. Replace the unit. c. See manufacturer's instructions.
14. Compressor short-cycles (poor refrigeration effect).	a. Loose electrical connections b. Defective thermostatic switch c. Defective motor starter d. Air restriction at evaporator	a. Locate loose connections and make them secure. b. Replace thermostatic switch. c. Replace defective motor starter or relay. d. Remove air restriction.
15. Compressor short-cycles (no refrigeration).	a. Dirty condenser b. Ambient temperature too high c. Defective wiring d. Thermostatic switch operating erratically e. Relay erratic	a. Clean the condenser. b. Provide ventilation or move to a cooler location. c. Repair or replace defective wiring. d. Replace thermostatic switch. e. Replace relay.
16. Compressor runs too frequently.	a. Poor air circulation around the condenser or too high ambient temperature b. Load too great; worn compressor; generally accompanied by rattles or knocks	a. Increase the air circulation around the condenser. In some localities the temperature is extremely high and nothing can be done to correct this. b. Analyze end use. Replace unit or bring it to the shop for repairs.

TABLE 2-1 (Continued)

TROUBLESHOOTING GUIDE FOR SELF-CONTAINED AIR-CONDITIONERS

COMPLAINT	CAUSE	POSSIBLE REMEDY
17. Compressor does not run.	Motor not operating	If the trouble is outside the sealed unit, it should be corrected; for example, wires should be repaired or replaced and thermostatic switches or relays should be replaced. If the trouble is inside the sealed unit, the sealed unit should be replaced.
18. Compressor will not run. (Assume that the thermostatic switch and relay, and the electric wiring and current supply are in good condition and operating normally.)	a. If the cabinet has been moved, some oil may be on top of the piston.	a. Wait an hour or so, and then attempt to start the motor by turning the current on and off many times. On some compressors, it may be necessary to wait 6 or 8 hours.
	b. Compressor may be struck, or some parts may be broken.	b. Replace the unit.
	c. Connections may be broken on the inside of the unit, or the motor winding may be open.	c. Replace the unit. Sometimes after sealed units have been standing idle for a long time, the piston may stick in the cylinder wall. It is sometimes possible to start the compressor by turning on the current and bumping the outer housing with a rubber mallet.
19. Compressor is unusually hot.	a. Condenser dirty or lack of air circulation	a. Clean the condenser; increase the air circulation.
	b. Unusually heavy service or load	b. If possible, decrease load. Perhaps another unit is required.
	c. Low voltage	c. This could be caused by too small feed wires. If the wires feeding the refrigerating unit become warm, it is an indication that they are too small and should be replaced by larger wires.
	d. A shortage of oil	d. Add oil if possible; if this is not possible, the unit must be replaced. A shortage of refrigerant will cause a shortage of oil in the crankcase of the compressor.
20. There is no refrigeration after starting.	Generally, during a long shutdown, an amount of liquid refrigerant will get into crankcase of the compressor. When this happens, the compressor operation will cause no noticeable refrigeration effect until all the liquid refrigerant has evaporated from the crankcase.	Allow the compressor to operate until its internal heat drives the liquid refrigerant from the crankcase. Under some conditions, this may take as long as 24 hours. This time can be shortened by turning an electric heater on the compressor and raising the compressor temperature, not exceeding 110 °F.

TABLE 2-1 (Continued)

TROUBLESHOOTING GUIDE FOR SELF-CONTAINED AIR-CONDITIONERS

COMPLAINT	CAUSE	POSSIBLE REMEDY
21. Compressor is noisy.	a. Mountings have become worn or deteriorated. The walls against which the unit is placed may be of an extremely hard surface and may resound and amplify the slight noise from the compressor into the room.	a. Replace the rubber mountings. Place a piece of sound-absorbing material on the wall against which the unit is placed, or move the unit to a new location.
	b. Shortage of oil and/or refrigerant	b. Add oil and refrigerant if possible. If it is impossible, the unit must be replaced.
	c. The sealed unit mechanism has become worn.	c. Replace the unit.
22. After each defrosting, there is a long cycle before refrigeration is again normal.	a. Slight shortage of refrigerant	a. Add refrigerant if possible; if not, replace the unit.
	b. Condenser is dirty.	b. Clean the condenser.
	c. Thermostatic switch bulb is loose.	c. Secure the bulb in place.
	d. There is a restriction between the receiver or condenser and/or the evaporator.	d. Attempt to remove the restriction by jarring with a plastic hammer or by heating the possible points of restriction to about 110 °F. If this does not correct the trouble, the unit must be replaced or brought to the shop for repairs.

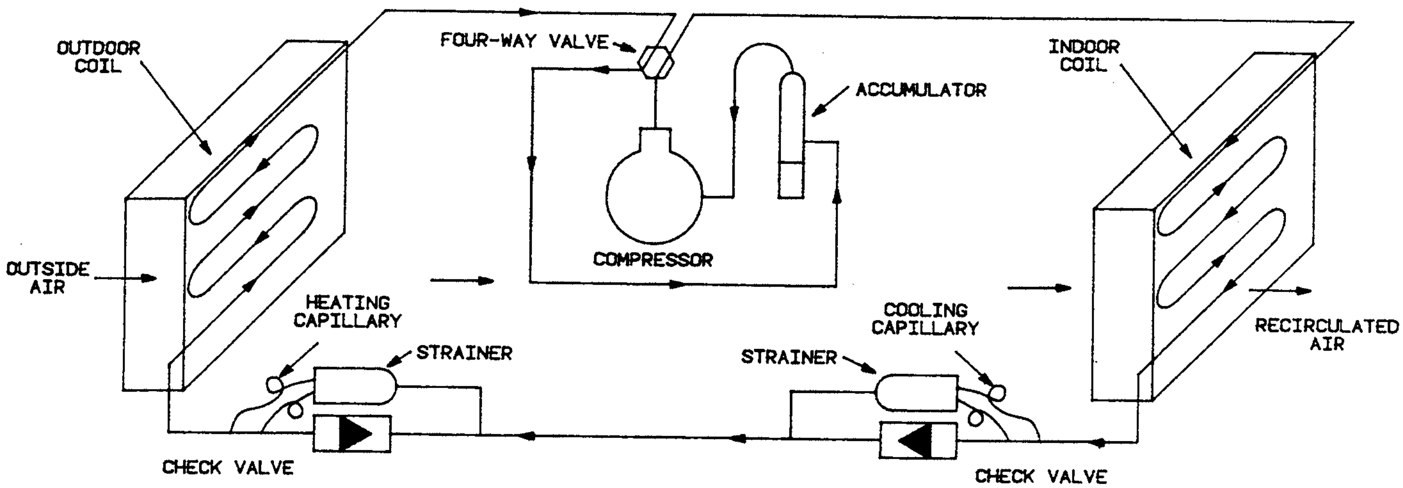


Figure 2-8

HEAT PUMP HEATING CIRCUIT

in the line between the indoor and outdoor coils, allows the outdoor coil to operate as the condenser as in a regular air-conditioner. The defrost cycle is used during heat pump operation when, on a timed basis or by sensing lowered airflow across the outdoor coil, the heat pump reverses back to the cooling mode to raise the outdoor coil temperature in order to remove frost.

242 SPECIALIZED COMPONENTS

242.1 Four-Way Reversing Valve

A four-way interchange reversing valve causes a rapid change in direction of refrigeration flow resulting in a quick changeover from cooling to heat and vice versa.

242.2 Backup Heating

Under very low temperature conditions, the efficiency of a heat pump decreases. Some heat pumps are equipped with electric resistant heating coils to supplement the operation of the unit during cold weather.

243 INSTALLATION

Heat pumps may be installed either as a unitized system or as a split system with the indoor coil mounted in a distribution duct as a forced-air system. (See Figure 2-9 for examples of heat pump installation.)

244 MAINTENANCE GUIDELINES

Maintenance of heat pump systems requires operating under the same guidelines as any package air-conditioning unit. (See Part 224.) The proper refrigerant charge is very important in all heat pump systems because they operate under a wide variety of ambient conditions. Improper refrigerant charge can result in a number of undesirable conditions (sludge, acid, oil breakdown, etc.) any of which may cause compressor failure. Always refer to the manufacturer's instructions for refrigerant checking and charging procedures. A sample preventive maintenance checklist for heat pumps is included in Exhibit 2-3 (Appendix C). See Table 2-2, "Troubleshooting Guidelines for Heat Pumps."

TABLE 2-2

TROUBLESHOOTING GUIDE FOR HEAT PUMPS

COMPLAINT	CAUSE	POSSIBLE REMEDY
1. Heat pump will not operate.	a. Disconnect switch off	a. Turn switch on. Both disconnect switches must be on in remote system.
	b. Incorrect thermostat setting	b. Change to proper setting.
	c. Tripped circuit breaker or unit fuse	c. Turn unit disconnect switch(es) off. Check unit fuses and replace with same size and type fuse.
2. Unit runs but there is little heat.	a. Obstructed outdoor coil	a. Remove obstruction.
	b. Dirty or plugged air filter	b. Clean or change if necessary.
3. Reversing valve will not shift from heat to cool.	a. No voltage to coil	a. Repair electrical current.
	b. Defective coil	b. Replace coil.
	c. Low refrigerant charge	c. Repair leak and recharge system.
	d. Pressure differential too high	d. Reset differential.
	e. Pilot valve operating correctly (dirt in one bleeder hole).	e. Deenergize solenoid, raise head pressure, reenergize solenoid to break dirt loose. If unsuccessful, remove valve and wash out. Check on air before installing; if no movement, replace reversing valve, add strainer to discharge tube, and mount valve horizontally.
	f. Piston cup leak	f. Stop unit. After pressure equalizes, restart with valve solenoid energized. If valve shifts, reattempt with compressor running. If still no shift, replace reversing valve.
	g. Clogged pilot tubes	g. Raise head pressure and operate solenoid to free tube of obstruction. If still no shift, replace reversing valve.
	h. Both ports of pilot open. Back seat port did not close.	h. Raise head pressure and operate solenoid to free partially clogged port. If still no shift, replace reversing valve.
4. Reversing valve starts but does not complete reversal.	a. Not enough pressure differential at start of stroke, or not enough flow to maintain pressure differential	a. Check unit for correct operating pressures and charge. Raise head pressure. If no shift, use valve with smaller ports.
	b. Body damage	b. Replace reversing valve.
	c. Both ports of pilot open	c. Raise head pressure and operating solenoid. If no shift, replace reversing valve.
	d. Valve hung-up at midstroke; pumping volume of compressor not sufficient to maintain reversal	d. Raise head pressure and operate solenoid. If no shift, use a reversing valve with smaller ports.

TABLE 2-2 (Continued)

TROUBLESHOOTING GUIDE FOR HEAT PUMPS

COMPLAINT	CAUSE	POSSIBLE REMEDY
5. Reversing valve has apparent leak in heating position.	a. Piston needle on end of slide leaking	a. Operate reversing valve several times, then recheck. If excessive leak, replace valve.
	b. Pilot needle and piston needle leaking	b. Operate reversing valve several times,
6. Reversing valve will not shift.	a. Pressure differential too high	a. Stop unit. Valve will reverse during equalization period. Recheck system.
	b. Clogged pilot tube	b. Raise head pressure. Operate solenoid to free dirt. If still no shift, replace reversing valve.
	c. Dirt in bleeder	c. Raise head pressure and operate solenoid. Remove reversing valve and wash it out. Check on air before installing; if no movement, replace valve. Add strainer to discharge tube. Mount valve horizontally.
	d. Piston cup leak	d. Stop unit. After pressure equalizes, restart with solenoid deenergized. If valve shifts, reattempt with compressor running. If it still will not reverse while running, replace reversing valve.
	e. Defective pilot	e. Replace valve.

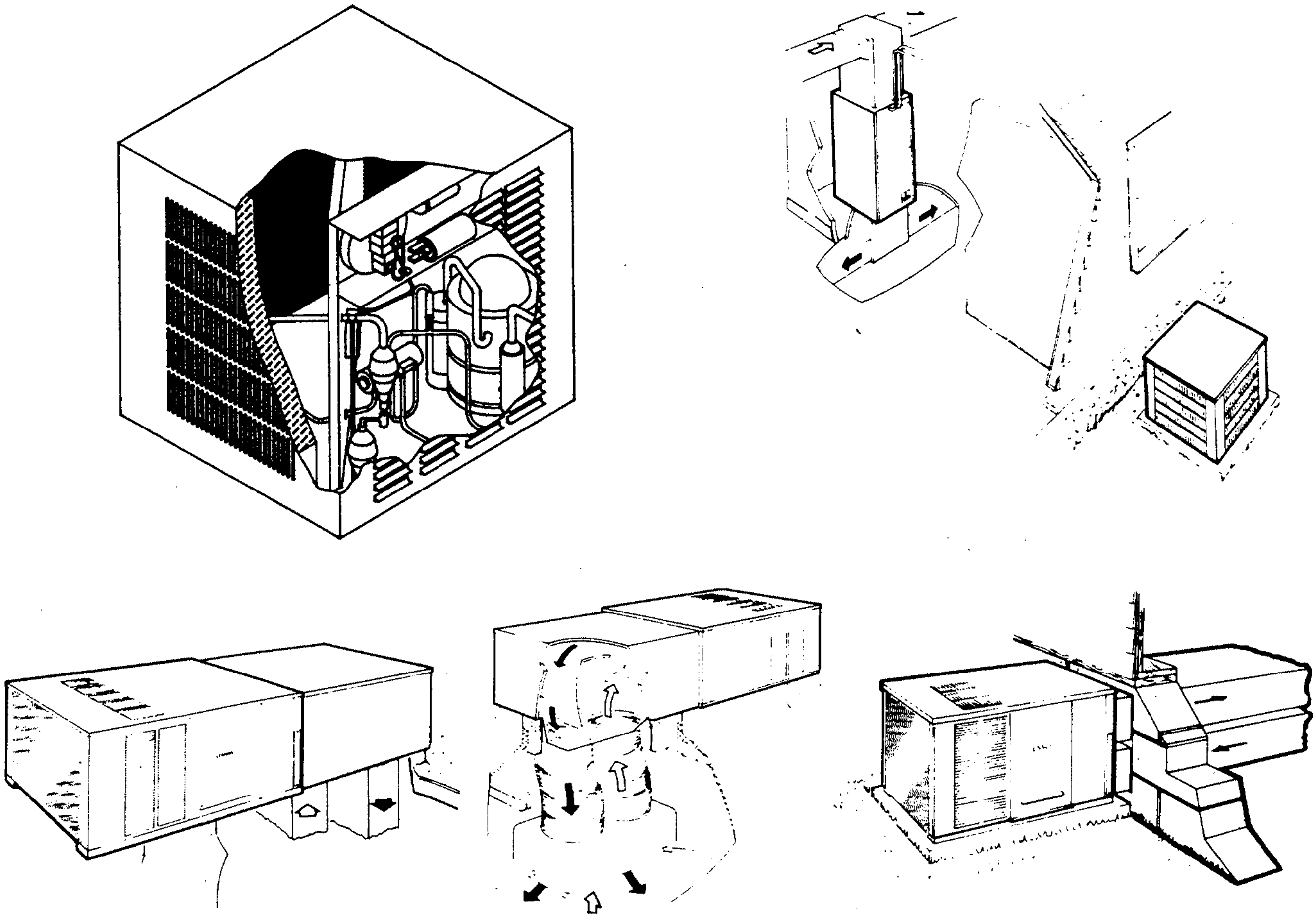


Figure 2-9

EXAMPLES OF HEAT PUMP INSTALLATION

250 GAS FORCED-AIR FURNACES

251 OPERATION

Some smaller postal facilities are heated by one or more forced-air furnaces. These units supply the facility with conditioned air via sheet metal ducts. They also can be ceiling mounted to provide heated air by the method of free discharge. To provide heat, air is drawn into the furnace by convection created by ignition of the burner flame. A small percentage of this combustion air is mixed with natural gas and ignited as it exits from the burners. The remainder of the combustion air continues past the burners where it is heated and rises past the heat-exchanger shell. During the passage of the hot combustion air through the heat exchanger, heat is transferred from the air to the heat exchanger. After passing through the heat exchanger, the cooled combustion air exits the furnace through the vent

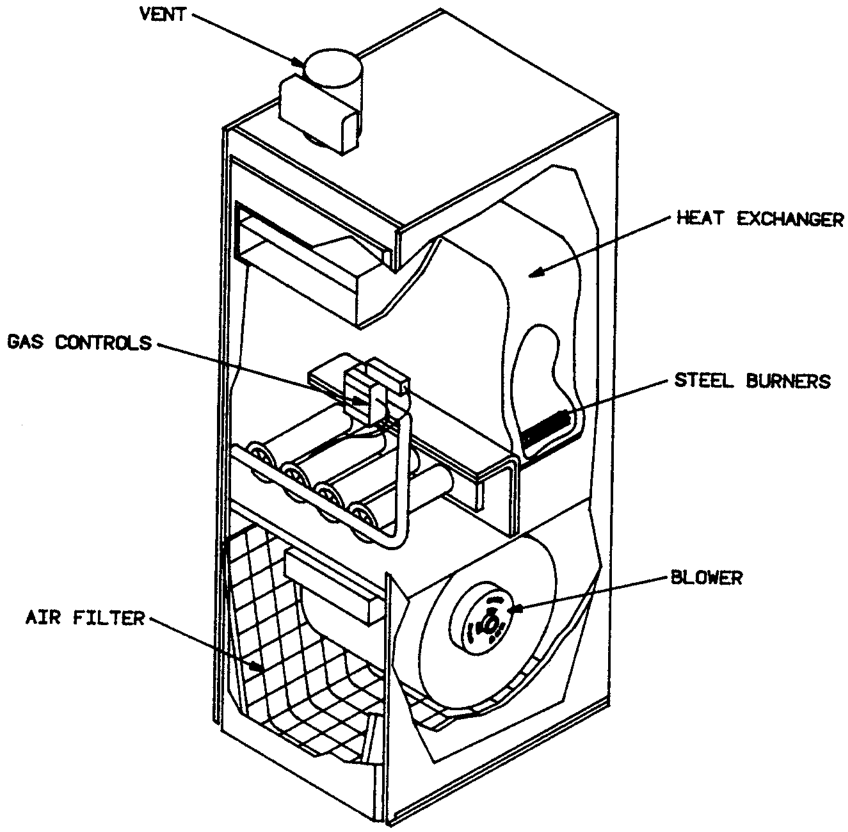


Figure 2-10
FORCED-AIR FURNACE

which exhausts outside of the facility. Building interior air is drawn into the furnace by a blower. This air passes through a filter and is then directed to the heat exchanger where it is heated and forced into the area surrounding the furnace or into distribution ducts. (See Figure 2-10.)

252 COMPONENTS

252.1 Solenoid Valve

Gas forced-air furnaces provide a safety shutoff and gas control via the use of a low-voltage solenoid valve. The solenoid also functions as an automatic safety for the pilot flame via a thermocouple sensor, and provides gas pressure regulation.

252.2 Filter(s)

The filter(s) keeps the heat-exchanger surfaces clean in order to maintain effective heat transfer. Filters should be cleaned or replaced regularly.

252.3 Blower

The blower draws air into the furnace from either return air ducts or the area surrounding the furnace. It forces air around the heat exchanger and into supply ducts or the surrounding air.

252.4 Heat Exchanger

The heat exchanger transfers heat between the hot combustion air and the building interior air, while eliminating the possibility of combustion air and gas residues mixing with the building interior air.

252.5 Burner

The burner ensures that the flame created by the combustion of natural gas is of uniform size and mixture and achieves good combustion efficiency.

252.6 Vent

The vent or flue removes combusted air and gases from the furnace and exhausts them outside of the building.

WARNING

> The vent should be practically airtight to prevent carbon monoxide gas from building up inside the building.

253 MAINTENANCE GUIDELINES

253.1 Flue Maintenance

The integrity of the flue should be maintained at all times to prevent leakage of carbon monoxide. If two or more appliances vent to a common flue, the area of the common flue should be at least equal to the area of the largest flue or vent connector plus 50 percent of the combined area of additional flues or vent connector.

NOTE

> When checking performance, derate the rated Btu/hr capacity by 4 percent for each 1,000 feet beyond a 2,000-foot altitude above sea level.

253.2 Piping Maintenance

When repairing and installing gas piping, carefully check all the connections with a soap solution to detect the presence of leaks. When using compound on threaded pipe joints, always ensure that it is resistant to the action of liquified petroleum gases. A sample preventive maintenance checklist is contained in Exhibit 2-4 (Appendix C).

260 OIL-FIRED HOT-WATER BOILERS

261 OPERATION

Many older and smaller post offices are heated by oil-fired hot-water boilers. These units operate on the same principles as larger boilers, but differ in construction design. These units operate on No. 2 fuel oil and, when their design capacity is less than 400,000 Btus per hour, are like the design shown in Figure 2-11. To release the heat energy from the fuel oil, the oil-fired burner initially ignites the fuel by forcing small atomized droplets past an electrical spark generated between two high voltage electrodes. The heat from the spark causes the oil droplets to become oil vapor and burn continuously. This burning then heats the surrounding oil droplets, igniting them. This process continues until all or most of the droplets are vaporizing and burning. If conditions for combustion are ideal, all oil droplets

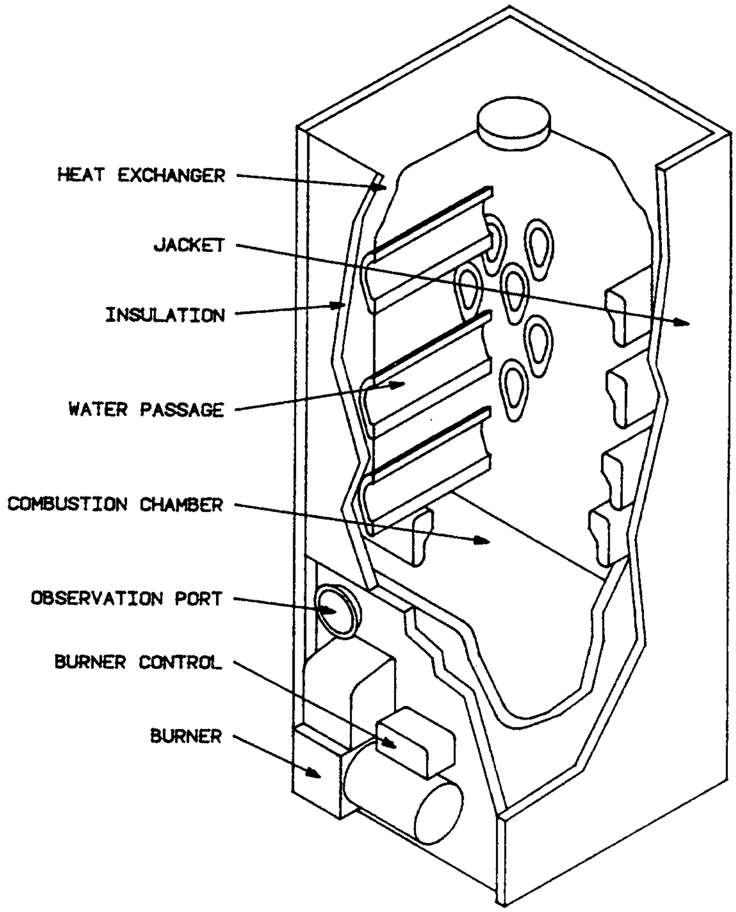


Figure 2-11
OIL-FIRED HOT-WATER BOILER

will burn completely and cleanly within the combustion zone.

262 COMPONENTS

262.1 Jacket

The jacket provides an insulated covering for the heat exchanger.

262.2 Heat Exchanger

Generally constructed of cast iron, the heat exchanger allows the transfer of heat between the heated air created by the boiler flame and the cooler water circulated through the exchanger. This transfer takes place in two ways, by hot combustion gases directly contacting the heat-exchanger surfaces, or by radiant energy in the combustion chamber heating the exchanger surfaces.

262.3 Combustion Chamber

The combustion chamber is designed to surround the flame and radiate heat back into the flame to aid in combustion. The chamber must be made of the correct material, properly sized for the burner nozzle firing rate, and shaped correctly to ensure unburned droplets of oil do not touch the chamber. An additional consideration, in the selection of material used to construct the chamber, is the reduction of noise generated by the burner. Often a soft, sound-attenuating material is selected.

262.4 Burner

The burner package incorporates several functions. It must provide a properly mixed combination of air and oil. It must provide ignition of this mixture and ensure that the combustion achieves a desired flame size and shape. The components of a burner package are shown in Figure 2-12. Their functions are as follows:

a. Drive Motor. The drive motor powers both the blower and the fuel unit.

b. Blower. The blower provides airflow sufficient to force the air and fuel oil mixture into the combustion chamber.

c. Bulk Air Band. This device provides gross adjustment of the quantity of air mixed with vaporized oil.

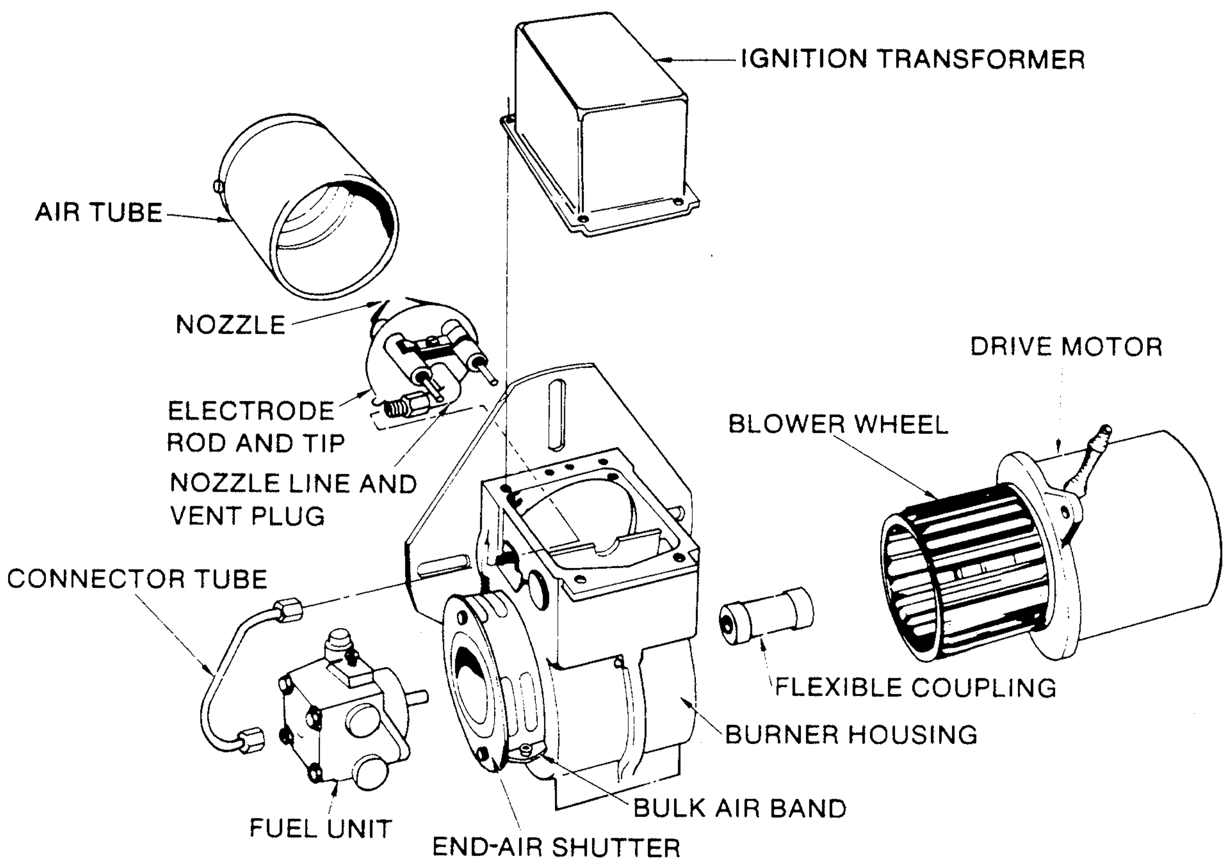


Figure 2-12

COMPONENTS OF A BURNER PACKAGE

d. End-Air Shutter. This device provides the fine adjustment of the quantity of air mixed with vaporized oil.

e. Fuel Unit. This "pump" draws oil from the storage tank to the burner unit. Additionally, it pressurizes the oil (normally around 100 psi) being fed into the burner nozzle, forcing the oil through the small nozzle orifice in order to break it down into atomized particles.

f. Nozzle. The nozzle breaks the oil down into atomized particles. It determines the rate at which oil is burned and affects both the shape and efficiency of the flame.

g. Electrodes. The electrodes ignite the vaporized oil when the furnace is first started, and until the flame becomes self-sustaining.

h. Ignition Transformer. The transformer provides a high-voltage spark across the electrodes (normally around 10,000 volts) in order to ignite the fuel/air mixture when the furnace initially starts.

i. Air Tube. The air tube controls flame shape by creating a desired airflow pattern as the air/fuel mixture ignites and enters the combustion chamber.

j. Burner Control. The burner control provides control over the burner motor, ignition system, and oil valve. (Not shown in Figure 2-12.)

k. Flame Control. The flame-control circuit provides a means of shutting down the burner if, during startup or when running, the flame in the burner fails to ignite or is extinguished. (Not shown in Figure 2-12.)

262.5 Auxiliary Controls and Equipment

Auxiliary controls and equipment are as follows:

a. High-Limit Aquastat. The aquastat shuts down the burner when the operating temperature is exceeded.

b. Circulator. The circulator pumps heated water throughout the water loop. (See Figure 2-13.)

c. Operating Aquastat. The aquastat shuts down the burner when the operating temperature is met.

d. Pressure-Relief Valve. The pressure-relief valve opens to release water when the hot water in the boiler exceeds either the desired safe temperature or pressure. (See Figure 2-13.)

e. Low-Water Cutoff. The low-water cutoff shuts down the boiler if water in the boiler drops below a safe level.

f. Flue. The flue vents products of combustion from the furnace to outside the building. (See Figure 2-13.)

g. Damper. The damper controls the airflow or "draft" through the furnace in order to ensure efficient combustion. (See Figure 2-13.)

263 MAINTENANCE GUIDELINES

263.1 General Maintenance

a. The oil-line filter should be replaced every year to avoid contamination of the fuel unit or atomizing nozzle.

b. The atomizing nozzle should be replaced every year.

c. If a chemical cleaner is used on the fireside of the heat exchanger, be

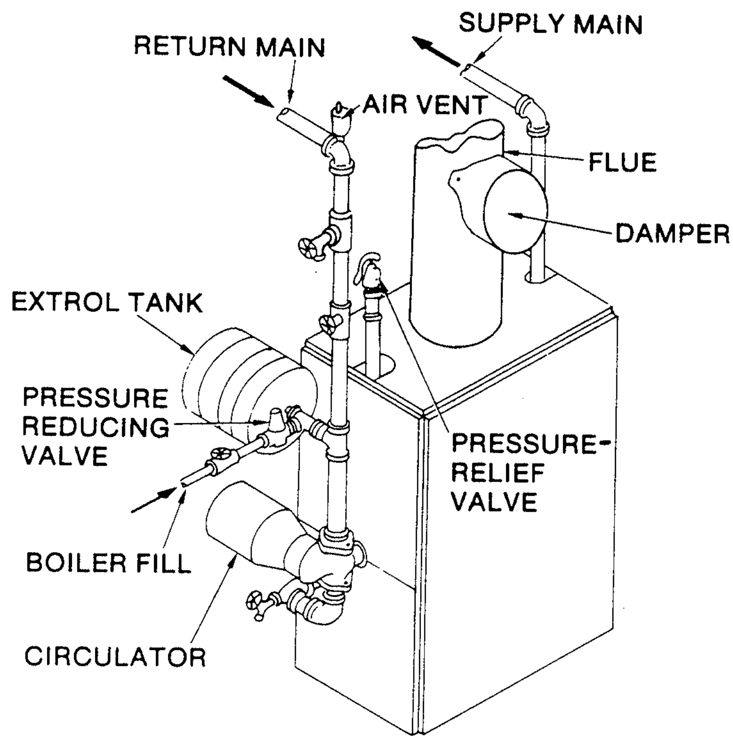


Figure 2-13

BOILER SYSTEM

sure that it is compatible with the material used to construct the combustion chamber.

d. The area around the heating unit must be kept clean and free of any combustible materials--especially paper and oily rags.

CAUTION

Never burn garbage or refuse in the unit. Never try to ignite oil by tossing burning papers or other material into the unit.

263.2 Combustion Efficiency Guidelines

.21 General Procedures. On an annual basis, combustion efficiency of the burner should be checked and, if required, adjusted. The following is the procedure for determining boiler combustion efficiency:

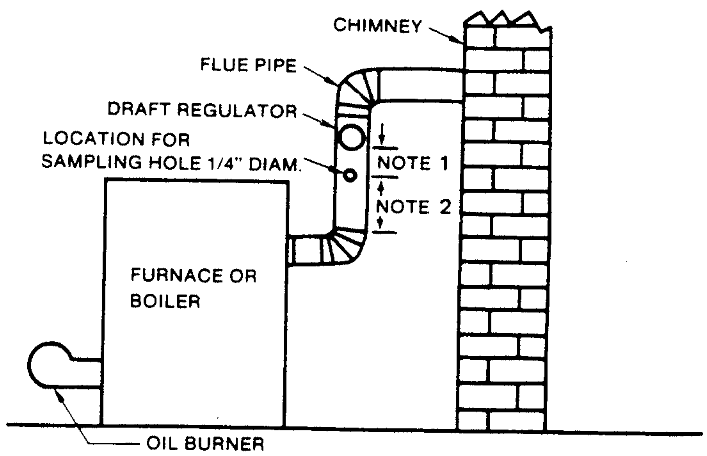
a. If not already equipped, drill flue pipe sampling holes as shown in Figure 2-14.

b. Calibrate and check the operation of the measuring equipment.

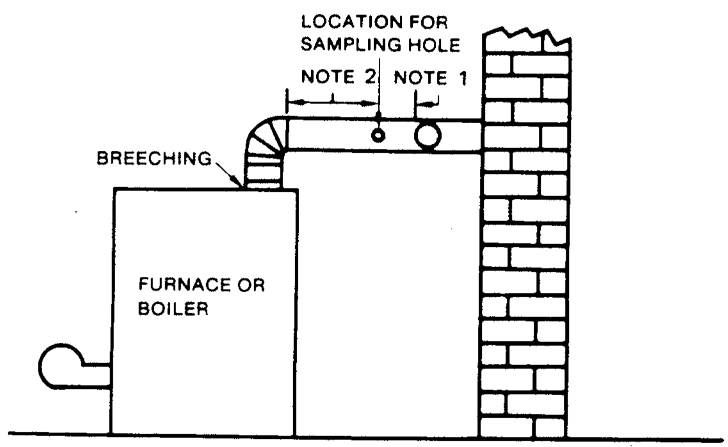
c. Replace the atomizing nozzle and oil-line filter. The nozzle should match the design load. DO NOT OVERSIZE.

d. To ensure prompt ignition, adjust the ignition electrodes according to burner manufacturer's instructions.

e. Operate the burner, adjust the air setting until a good flame appears, and run the burner for at least 10



VIEW A
HORIZONTAL FLUE CONNECTION



VIEW B
VERTICAL FLUE CONNECTION

Desirable location for 1/4 " flue pipe sampling hole for typical chimney connections

1. Locate hole at least 1 flue pipe diameter on the furnace or boiler side of the draft control.
2. Ideally, hole should be a least 2 flue diameters from breeching or elbow.

Figure 2-14
PLACEMENT OF FLUE PIPE SAMPLING HOLE

minutes or until operation has stabilized.

f. Check burner pressure. Bleed air from the pump and nozzle piping, and check the nozzle piping. Check the pump pressure and adjust it to 100 psi, if necessary (or to manufacturer's recommendation).

.22 Draft Readings. Check the draft reading over the fire using a draft gauge by way of a 1/4-inch hole drilled in the fire or inspection door. (This hole should be in the inspection door for oil-fired matched units, or in the fire door for conversion installations. If possible, the hole should be above the flame level.) Adjust the barometric-draft regulator on the flue to give the overfire draft recommended by the manufacturer. If no such recommendations are available, set the overfire draft to ensure a negative pressure within the combustion chamber (usually 0.02 inches water column). With some equipment, it will not be possible to take draft readings over the fire. In this case, adjust the draft regulator to give a breech draft reading between 0.04 and 0.06 inches water column (taken at the sampling hole).

NOTE

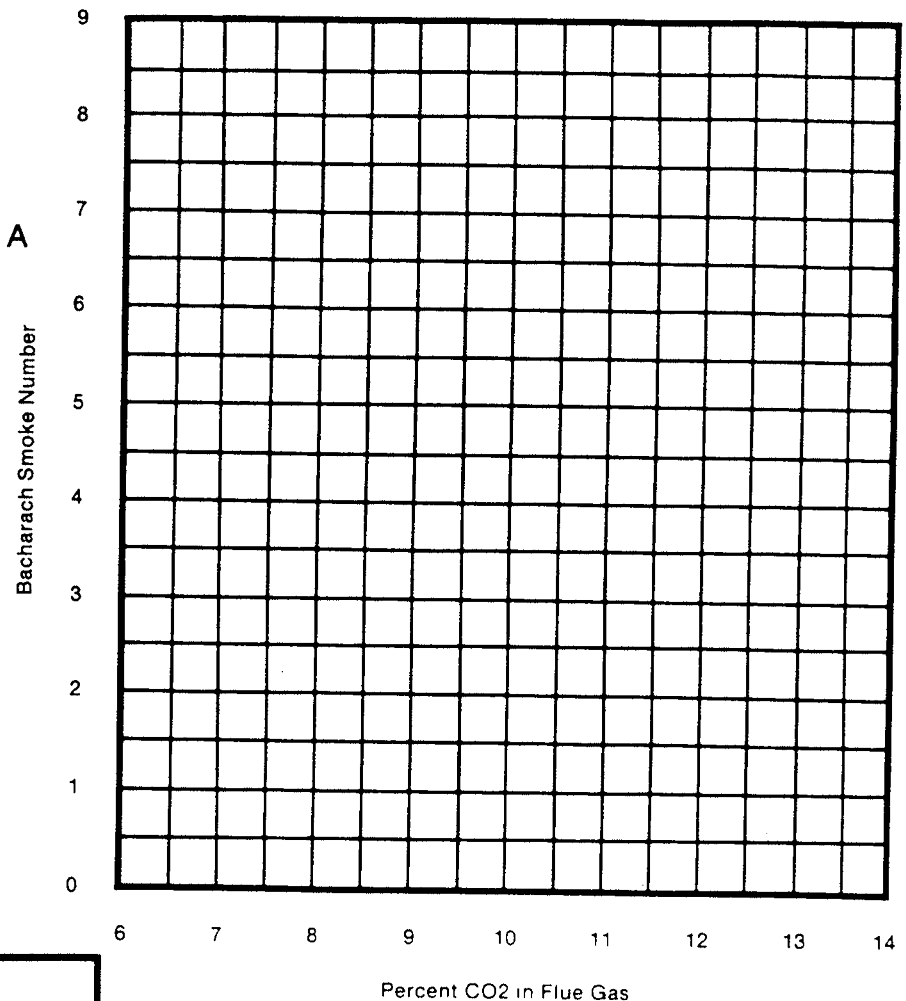
After these tests have been made, seal the draft or sampling hole in the inspection or fire door using a plug, bolt, or high-temperature sealant. The flue sampling hole should also be sealed.

.23 Smoke Readings. After the burner has operated for 5 or 10 minutes, make a smoke measurement in the flue, following the smoke tester instructions. Oily or yellow smoke spots on the filter paper are usually a sign of unburned fuel, indicating very poor combustion (and likely high emissions of carbon monoxide and unburned hydrocarbons). This condition can sometimes be caused by not enough air. If this condition cannot be corrected, major renovation or even burner replacement may be necessary.

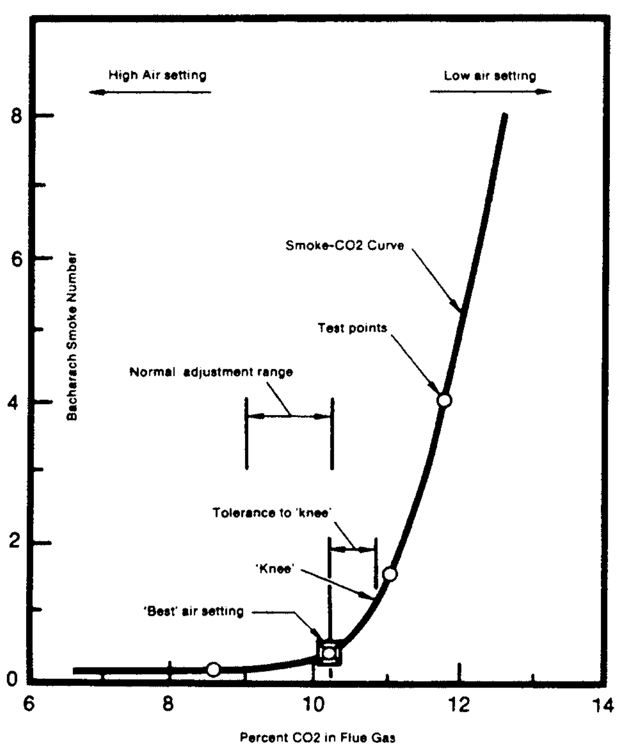
.24 Smoke-CO_2 Curve Development. Record measurements of smoke and CO_2 from the flue. Then, establish the Smoke-CO_2 Curve by taking readings over a range of air settings. (See Figure 2-15.) To do this, start with the air gate almost fully open and then take smoke and CO_2 readings at progressively lower air settings, as necessary to visualize the general shape of the curve. (The CO_2 readings will increase as the air setting is decreased, unless combustion is incomplete.) Do not set the air gate to give a smoke reading above No. 1. Plot the points on a copy of the charts shown in Figure 2-15A. Usually 3 or 4 readings are enough to establish the curve. In adjusting each air setting, it is helpful to note the various positions of the air gate at which measurements are made so that the final setting can be located quickly.

.25 Air Setting Adjustment. Examine the Smoke-CO_2 plot and, keeping in mind the large increase in smoke in relation to a small increase in CO_2 shown by the curve of Figure 2-15B, note the location of the "knee" where the smoke number begins to rise sharply. Noting the air gate position marks, adjust the air setting to a CO_2 level 1/2 to 1 percent lower than the CO_2 level at the "knee." (This provides a tolerance against possible shifts in the setting over time.) Do not increase the air setting any more than necessary on the lower portion of the curve below the "knee." Lock the air adjustment and repeat draft, CO_2, and smoke measurements to make sure the setting has not shifted.

VIEW A



VIEW B



Typical air adjustment for different types

OIL-BURNER TYPE	Typical CO2 In Flue Gas When Tuned*
HIGH-PRESSURE GUN-TYPE BURNERS	
• Old-Style Gun Burners -No internal air-handling parts other than an end cone and stabilizer	8%
• Newer-Style Gun Burners -special internal air-handling parts	9%
• Flame-Retention Gun Burners -flame-retention heads	10%
OTHER TYPES OF BURNERS	
• Atomizing Rotary Burners -ABC, Hayward etc	8%
• Rotary Wall-Flame Burners -Timken, Fluid-Heat, Torridheat, etc	12%
• Miscellaneous Low-Pressure Burners	**

*Based on acceptable Bacharach smoke--generally No 1 or trace, but not exceeding No. 2. Caution should be used in leaving burners with CO2 level higher than 13%.

**See manufacturer's instructions

VIEW C

Figure 2-15

SMOKE-CO_2 CURVE

NOTE

The characteristic curve for some burners may not yield a distinct "knee" in the curve. In such cases, the setting should be made near the minimum smoke setting (using judgment).

.26 Performance Check. A well-matched and well-tuned burner should be capable of operation with smoke not greater than No. 1 and at a CO_2 level not less than listed in the table, Smoke-CO_2 Curve Sheet, Figure 2-15C. If this cannot be reached, check the following:

a. Air Leaks. Air leaks into the combustion chamber or heat exchanger dilute the combustion gases and prevent normal CO_2 readings. Such leaks should be sealed with furnace cement or other high-temperature sealant. To check for dilution by leakage, measure the CO_2 at as high a point as possible over the fire, using a stainless steel tube inserted through the fire door sample hole (as described for overfire draft measurements in Section 263.22); compare this with the CO_2 measured in the flue. A difference of more than 1 percent CO_2 between the flue and overfire readings usually indicates air entry through leaks that have not been properly sealed. Seal between the probe and fire door sample hole during test. The fire door hole should be sealed when not being used to avoid leakage of air through it.

b. Air-Fuel Mixture. If the CO_2 level in the table on the Smoke-CO_2 Curve (Figure 2-15) still cannot be reached without exceeding No. 2 smoke, poor mixing of air and fuel is likely. This could be caused by a combustion head (blast-tube nosepiece) with too large a throat for good mixing, or an improper match between air and nozzle spray patterns. Frequently, replacement of the nozzle with another having a different spray angle and pattern improves performance. It may be necessary to replace the combustion head or try different settings if the burner is equipped with an adjustable head or mixing devices.

c. Unmatched Chambers. The combustion chamber must be matched in size and shape to the nozzle spray and the burner air pattern. Oversized chambers do not ensure adequate mixing. Undersized chambers may allow flame impingement on the chamber walls or heat exchanger.

.27 Stack Temperature Measurement. Operating the unit at an excessive firing rate generates more heat than the heat exchanger can utilize and results in unnecessary heat loss up the chimney. Other causes of excessive heat loss are badly sooted heat-exchanger surfaces and excessive draft. The temperature of the flue gas provides an indication of these heat losses. Measure net stack temperature by subtracting the room air temperature from the flue thermometer reading. Excessive stack loss is indicated if the net stack temperature during steady operation exceeds 400 to 600 ^{o}F for matched-package units, or 600 to 700 ^{o}F for conversion burners.

CAUTION

Significantly lower temperatures may be observed in properly adjusted burners when operating at high altitudes. Care should be taken that the stack temperature is not low enough to allow condensing of the flue gases in the breeching, as this will damage the breeching and chimney.

.28 **Ignition Check.** Check operation over repeated cycles to ensure prompt ignition on starting.

.29 **Pump Cutoff Check.** Slow pump cutoff at the end of a firing cycle can cause smoke and other pollutant emissions. Check for prompt pump cutoff by observing the flame or by testing smoke at shutdown. If poor cutoff is observed, ensure air is purged from the pump and nozzle line. Air trapped in the pump or nozzle line will expand when heated, causing oil to drip into the combustion chamber after shutdown. If poor cutoff persists, repair or replace the pump. (A solenoid valve in the nozzle line should ensure prompt cutoff. If it does not, replace or repair the solenoid.)

NOTE

Check the settings of all operating and limit controls before leaving the installation. A sample preventive maintenance checklist for oil-fired hot-water boilers is contained in Exhibit 2-5 (Appendix C).

270 WATER HEATERS

271 GENERAL

Adequate supplies of hot water must be provided to postal facilities in order to achieve health and sanitation standards. Water heaters range from units with several hundred gallon capacities to small point-of-use instantaneous types. Though some solar-powered systems have been installed, the bulk of domestic hot-water heaters in postal facilities are either electric or gas. Factors to be considered in evaluating hot-water heater use and selection are the capacity of the tank, the recovery rate in gallons per hour at a 90 °F water temperature rise, and the heater input requirements in watts or Btus per hour.

272 TANK-TYPE WATER HEATERS

Tank-type water heaters are the most common. These units contain a large tank heated by either a natural gas burner located beneath the tank, or by electric heater elements located in the side of the tank. While not as efficient as other style heaters, such as hydronic or point-of-use units, their low initial cost and wide availability make tank-type water heaters attractive.

273 COMPONENTS

273.1 Tank

The tank holds heated water. The design of the tank allows the heated combustion gases to cover the bottom of the tank before entering the vertical flue. Other openings in the tank are provided for water lines, temperature controls, and a drain valve. The tank is insulated to reduce heat transfer to the surrounding air.

273.2 Cathodic Protection

Because as it is heated it becomes more corrosive, water is called the universal solvent. The more dissolved mineral solids in the water, the greater its ability to carry electric current and cause corrosion. Corrosion results from a flow of electric current caused by a potential difference between two metals. Dissimilar metals present in a tank may be steel tank surfaces, drain-valve nipples, thermostat rods, magnesium anodes, and inlet and outlet nipples. New England, east coast and northwest areas have very soft surface water, but,

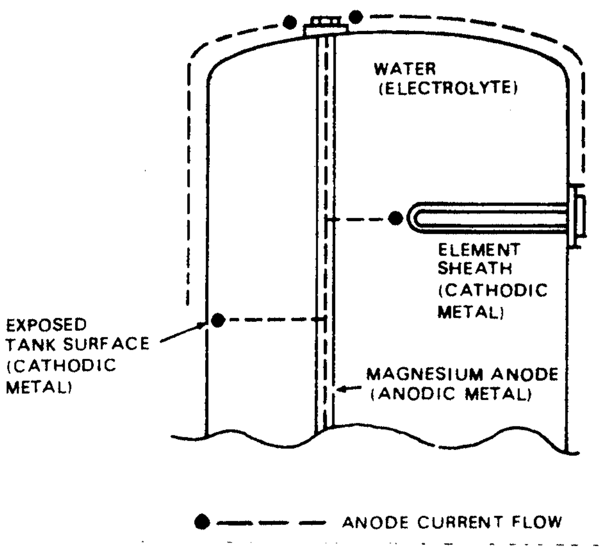


Figure 2-16

WATER HEATER ANODE

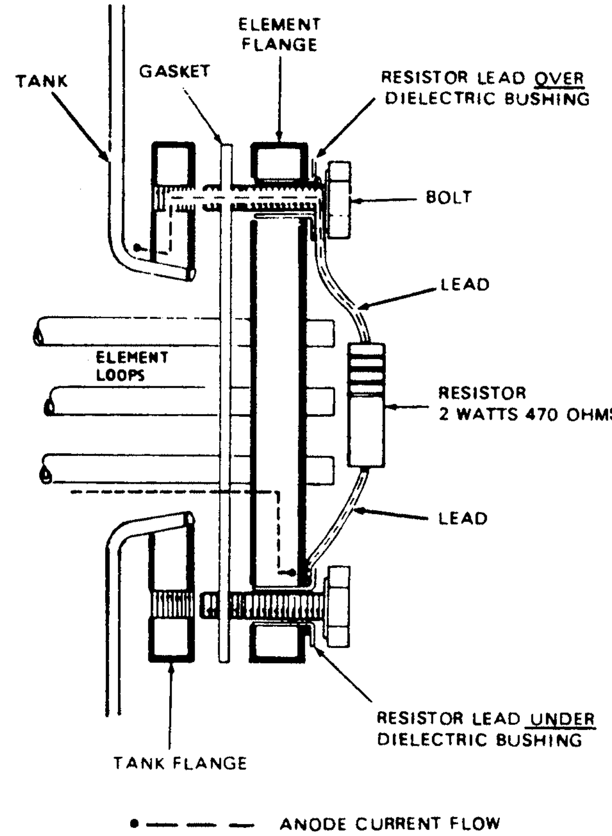


Figure 2-17

WATER HEATER HEATING ELEMENT

due to the large amounts of carbon dioxide (CO_2) gas dissolved in it, the water is very corrosive. Since much of it is supplied by wells, Midwestern and Southwestern water tends to be very hard. In the presence of these types of heated water, an electric current flows between dissimilar metals causing corrosion and gradual dissolution of one of the metals. To protect vital heater parts, an anode is installed in the water heater. This anode is generally made of an anodic or active material such as magnesium. See Figure 2-16 for an illustration of this process. On some electric water heaters, the heater elements also present a sufficiently large enough surface to quickly dissipate anodes. This is prevented by insulating the element from the tank and controlling the cathodic circuit current flow with a resistor. (See Figure 2-17.)

273.3 Valves

.31 Relief Valve. The relief valve has several functions. It is designed to protect life and property. Principles of this valve's function should be thoroughly understood, and the operation of this valve must never be defeated. The functions of the valve are:

a. Temperature relief. The valve is usually designed to be fully opened at a water temperature of 210 °F. This is sensed by the extension thermostat and protects the hot-water user from the possibility of being exposed to steam or the hazard of explosion. (See Figure 2-18.)

b. Pressure relief. The valve is designed to protect the water heating system from the damaging effects of high supply pressure, water hammer, and thermal expansion.

c. Test lever. The test lever should be lifted periodically to prevent lime buildup from sealing the discharge opening. The lever manually lifts the disc from the seat and indicates the condition of the waterway by the amount of flow observed.

WARNING

When replacing a hot-water heater, never reuse an old relief valve. These valves are matched to the heater pressure and temperature requirements, and use of a worn valve may compromise the safe operation of the new heater.

.32 Dip Tube. Water heaters with a cold-water inlet at the top of the tank have a dip tube leading toward the bottom. This tube delivers the incoming cold water through the stored water to the bottom of the tank. In doing this, cold water does not mix with hot water and is delivered to the area where it can be heated rapidly. The dip tube has a small hole located near the top end of the tube that prevents the hot water in the tank from being siphoned out by an interruption in the cold water supply.

.33 Drain Valve. The drain valve removes stored water from the tank when necessary. This draining removes solids from the bottom of the tank that may have settled out of the incoming water. Regular use of the drain valve to remove sediment from a gas-fired hot-water heater is especially necessary since the bulk of the heating occurs at the bottom of the tank and collected sediment reduces heat transfer efficiency.

273.4 Controls

.41 Heating Element. Electric water heaters use one or more electric heating elements immersed in the tank. These elements are comprised of a terminal for electrical connection, a mounting flange, a sheath to protect the heating wire from the water, magnesium oxide to insulate between the sheath and heating wire, and a resistance wire generally made of nichrome. (See Figure 2-19.)

.42 High-Limit Control. Electric water heater high-limit controls are resettable or nonresettable. The high-limit control stops the flow of electricity to the heating circuit when the tank surface adjacent to the device reaches a predetermined temperature. This item is a safety device designed to protect against excessive water temperature caused by a defective thermostat or grounded heating element.

CAUTION

Whenever a high-limit control operates, the reason for operation must be determined.

.43 Thermostat. In electric water heaters, the thermostat is a discrete device. It is designed to be the primary device starting and stopping the flow of electricity to the heating elements.

.44 Thermocouple. Thermocouples consist of two dissimilar metals or wires joined together at a point called the "hot" junction. This junction, when

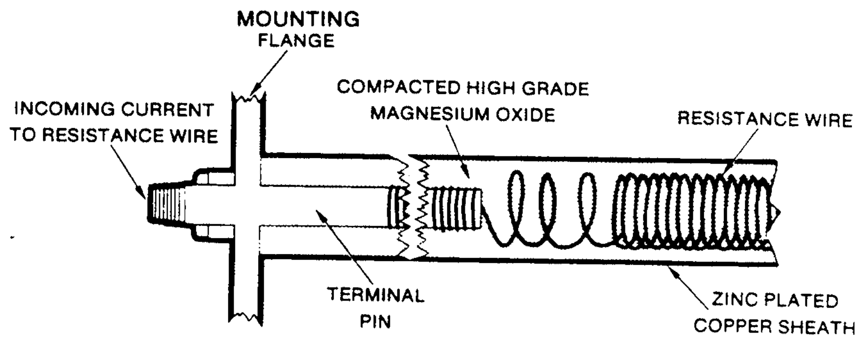


Figure 2-19

ELECTRIC HEATING ELEMENT

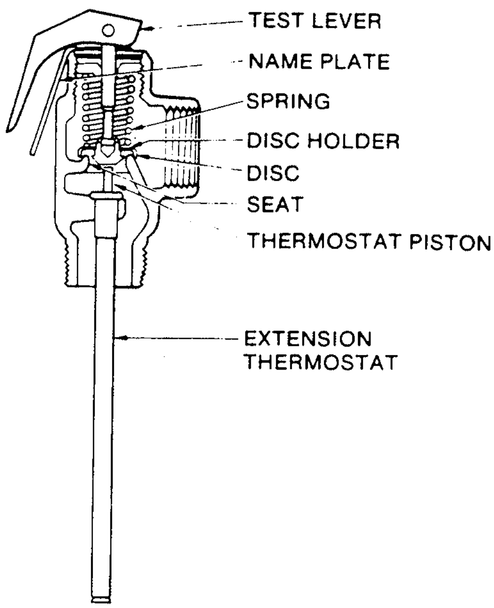


Figure 2-18

TEMPERATURE AND PRESSURE RELIEF VALVE

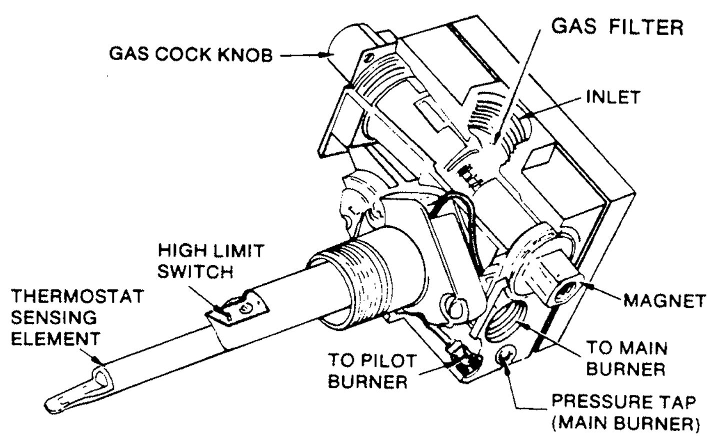


Figure 2-20

TYPICAL GAS CONTROL

subjected to heat, produces a potential difference between the two metals, generating current. This current is taken from the free ends of the metals at a point called the "cold" junction. The electric current generated by the thermocouple powers an electromagnet in the burner control which operates the burner.

.45 **Burner Control.** Gas-fired hot-water heater burners are operated via a burner control that provides the following controls (see Figure 2-20):

a. Thermostat. The thermostat controls water temperature. (Control knob not shown in Figure 2-20.) In accordance with postal energy conservation guidelines for water heaters serving washrooms, the thermostat should be adjusted to provide a delivered water temperature no warmer than 105 °F. Where the water heater supplies a kitchen or cafeteria, delivered water temperature should be 140 °F. Only kitchens that have a dishwasher without an internal heater require a delivered water temperature of 180 °F.

b. Gas cock. The gas cock is designed to cut off burner gas supply while the pilot is being manually lit.

c. High-temperature limit. When water temperature exceeds desired limits, gas flow is cut off by the high-limit switch.

d. Pilot safety. If the pilot fails, the gas control cuts off all gas to the burner and pilot.

e. Gas pressure regulation. The control maintains gas pressure at levels consistent with efficient burner and pilot operations.

f. Gas filter. Contaminants present in the natural gas supplied to the water heater are captured by the filter to prevent clogging of the control or burner.

273.5 Main Burner and Pilot

Gas-fired hot-water heaters are equipped with burners designed to provide a uniform flame. They may be either the upshot or annular venturi, depending on where the natural gas and air are mixed. The pilot provides an ignition source for the burner. (See Figure 2-21.)

273.6 Flue

The flue is designed to move the products of combustion through the heater to the chimney with a maximum of efficiency. The inside of the flue may be equipped with baffles to improve heat transfer by swirling the heated air as it rises through the flue.

273.7 Draft Hood

The draft hood prevents any change in the operation of the gas vent from affecting normal combustion within the heater. This device offers a ready means of escape for combustion products when there is no draft, a back draft, or actual stoppage within the vent itself. (See Figure 2-22.) The draft vent should be periodically checked to verify proper vent conditions. If the flame of a lighted match is drawn into the opening and continues to burn well, proper vent operation is present. If the match is blown away or snuffed out, the vent beyond the water heater must be checked to determine the cause of improper draft.

274 TANK WATER HEATER MAINTENANCE GUIDELINES

274.1 General Maintenance

.11 Any unit which exceeds any of the following limitations must be inspected by a boiler inspector:

a. Heat input of 200,000 Btu/hr

b. Water temperature of 210 ^{o}F

c. Nominal water capacity of 120 gallons or greater

.12 Water heaters should have a small amount of water drained periodically. The drain valve should be opened and water allowed to run until the water flow is clear of sediment. This prevents sediment buildup in the tank bottom.

.13 Relief valves should be periodically operated to prevent lime buildup.

NOTE

Should the water supply become contaminated, the tank should be chlorinated using a chlorine disinfectant such as household bleach (sodium hypochlorite). Check the manufacturer's or health department instructions for guidance.

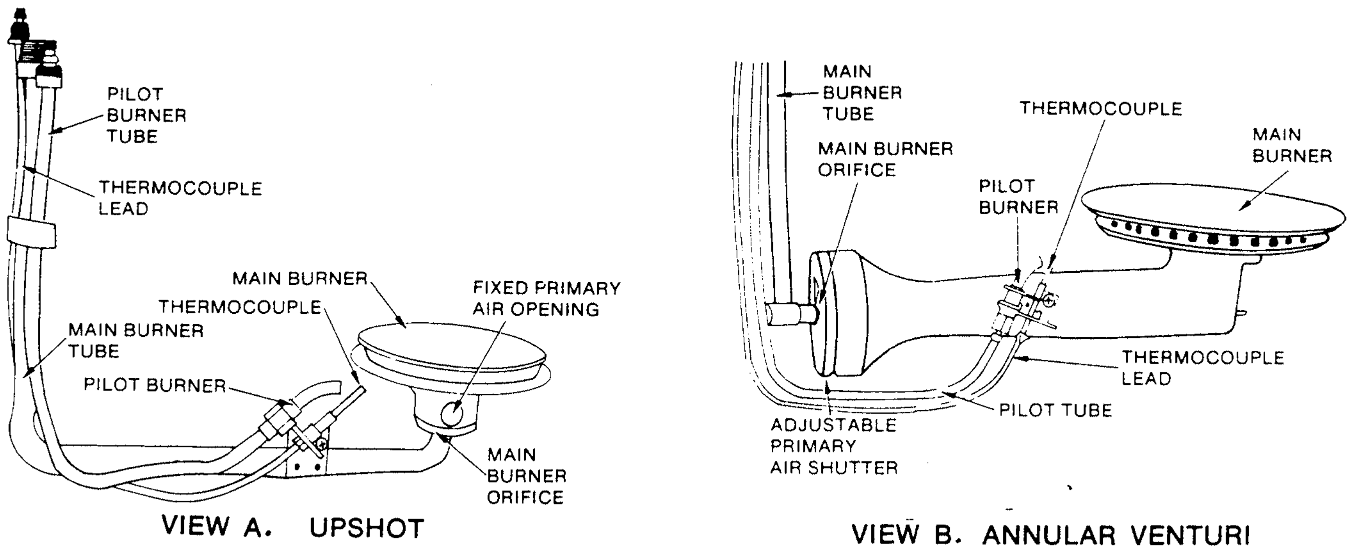


Figure 2-21

MAIN BURNER AND PILOT

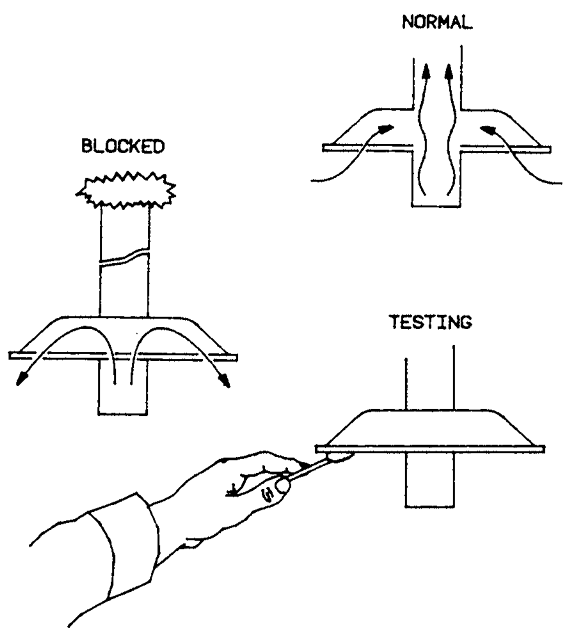


Figure 2-22

CHECKING VENT OPERATION OF DRAFT HOOD

WARNING

Always turn off and lock out the electrical power and turn off the gas when maintenance is being performed. Never touch electrical components with wet hands or if standing in water. Use insulated tools, if possible.

.14 Never operate the heating element without being certain the heater is filled with water.

.15 Water leaks should be corrected promptly. Leaks cause waste as follows:

60 drops/minute - 7 gallons/day

90 drops/minute - 10 gallons/day

120 drops/minute - 14 gallons/day

NOTE

See the Figures 2-23 and 2-24 for leakage checkpoints and corrective action.

274.2 Troubleshooting Guidelines

.21 **General.** For electric water heaters, the following operation of key components can be checked systematically using a voltmeter and jumper.

.22 **Power Check.** Conduct a power check as follows:

a. Turn off the electrical power to the water heater and remove the panels. Carefully open the insulation and, where used, remove the protectors over the controls.

b. Turn on the electrical power. Observe the meter when the leads are positioned across the top two terminals of the upper high-limit control. (See Figure 2-25A.)

c. If the full rated voltage indication is not obtained, check the electrical switch and fuses and, if necessary, the electrical connections on top of the heater.

d. Check across the two bottom terminals of the upper high-limit control. (See Figure 2-25B.) If full rated voltage is not obtained and the tank water temperature is 150 °F or below, push the reset button in the center of the high-limit control and retest. If full rated voltage is now obtained, the high-limit control was opened. This indicates the possibility of a defective heating element or thermostat. It may be necessary to cool the tank contents to reset the control.

.23 **Ground Check.** Check for "grounded" elements using the following procedure:

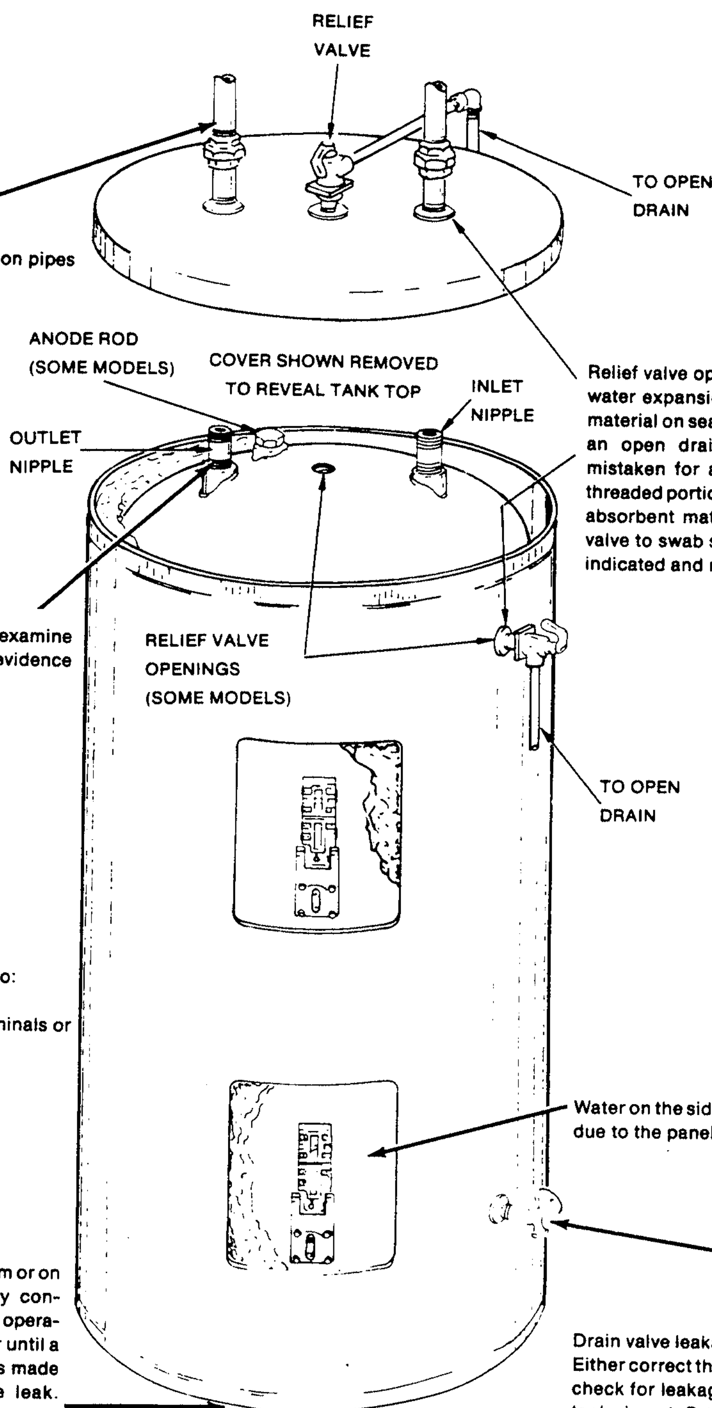
a. Turn off electrical power, lockout, and tag the circuit with Form 4707, Out of Order.

b. Remove the wires attached to elements.

c. Attach an end of the jumper cord to either of the two bottom terminals of the upper high-limit control. Bring the other end of the cord to the area of the element on test and attach it to one lead of the meter. (See Figure 2-26A.)

d. Turn on the electrical power and place the free test lead on either element terminal. The meter is in series with the element. (See Figure 2-26B.)

Full test voltage indicates the element is grounded and must be replaced. Partial or low voltage indicates the



Condensation and dripping may appear on pipes when cold water temperature is low.

Relief valve operation and leakage may be due to water expansion during heating cycle or foreign material on seat of valve. If the valve is not piped to an open drain, the released water could be mistaken for a leaking heater. To check where threaded portion enters tank, insert Q-tip or similar absorbent material between jacket opening and valve to swab spud area. Remove valve* if leak is indicated and repair with pipe joint compound.

Where possible, remove or lift top cover to examine threads of fittings installed into tank for evidence of leakage. Correct fitting leaks in field.

Water leaks at the elements may be due to:

1. Defective element which leaks at terminals or through flange. Replace element.
2. Loose element/gasket leak.

Water on the side of the tank may be condensation due to the panel or insulation not being in place.

All water which appears at the heater bottom or on the surrounding floor may be caused by condensation, loose connections, or relief valve operation and leakage. Do not replace the heater until a full inspection of all potential leak points is made and corrective steps taken to stop the leak. Leakage from other appliances, water lines, or ground seepage should also be suspected until proven otherwise.

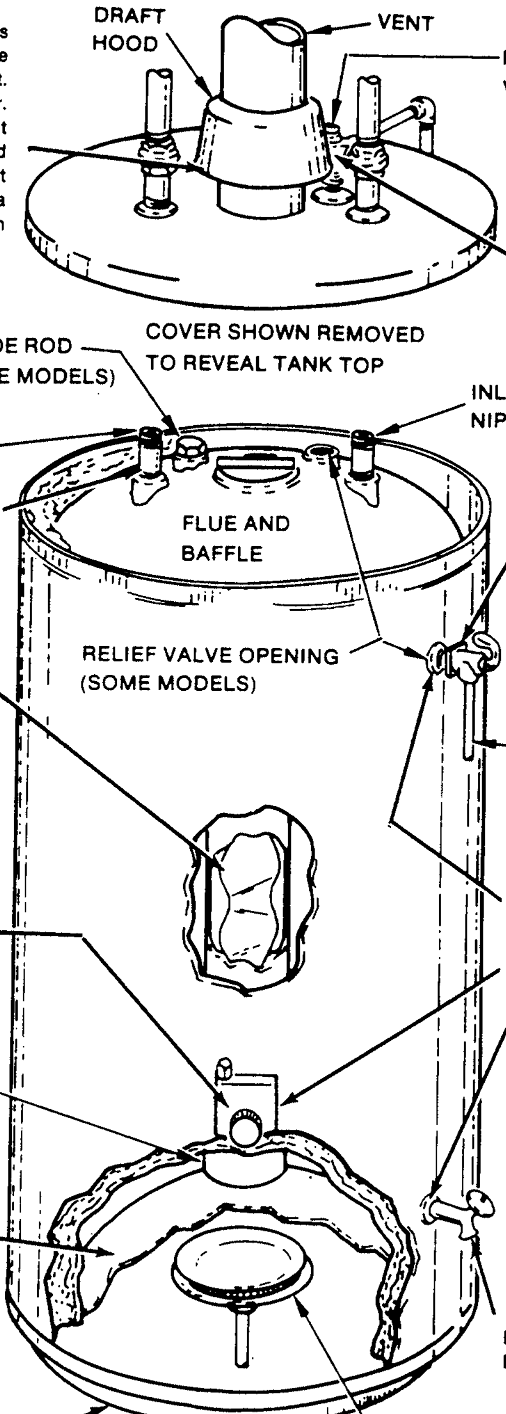
Drain valve leakage could be from the valve itself. Either correct the problem or replace the valve. To check for leakage where threaded portion enters tank, insert Q-tip or similar absorbent material between jacket opening and valve to swab spud area. Remove valve* if leak is indicated and repair with pipe joint compound.

*It is necessary to shut off electricity and drain tank to perform procedure.

Figure 2-23
ELECTRIC WATER HEATER CHECKPOINTS

Water leaking from the draft hood represents water vapor which has condensed out of the combustion products due to a problem in the vent. It may also be the result of leaking rainwater. Check draft hood operation with a match flame at the draft hood opening. Ideally, the burner should be on for about 10 minutes when making this test and, where connected to a common vent with a furnace, the furnace should be on. The match flame should be drawn into the draft hood.

Relief valve operation and leakage may be due to water expansion during heating cycle or foreign material on seat of valve. If the valve is not piped to an open drain, the released water could be mistaken for a leaking heater.



Where possible, remove or lift top cover to examine threads of fittings installed into tank for evidence of leakage. Correct fitting leaks in field.

Steady water leakage from the bottom of the flue into the burner may be caused by corrosive combustion products eating through the flue. Remove the draft hood and baffle to examine the flue passage. If the baffle is sooted and difficult or impossible to remove, corrosion should be suspected.

Occasional water leakage from the flue when the heater is operating suggests an improper vent. Check draft hood operation with a match as described above.

Water could be leaking from weep hole of gas control (where so equipped) or from spud where gas control enters tank.

To check where threaded portion enters tank, insert Q-tip or similar absorbent material between jacket opening and valve to swab spud area. Remove valve* if leak is indicated and repair with pipe joint compound.

Combustion products contain water vapor which can condense on the cooler surfaces of the tank forming droplets which drip into the fire or run out on the floor. This is common at the time of startup after installation, during periods of time when incoming water is cold or the heater may be undersized for the requirements.

Drain valve leaking could be from the valve itself. Either correct the problem or replace the valve.

All water which appears at the heater bottom or on the surrounding floor may be caused by condensation, loose connections, or relief valve operation and leakage. Do not replace the heater until a full inspection of all potential leak points is made and corrective steps taken to stop the leak. Leakage from other appliances, water lines, or ground seepage should also be suspected until proven otherwise.

*It is necessary to shut off gas and drain tank to perform procedure.

Figure 2-24

GAS WATER HEATER CHECKPOINTS

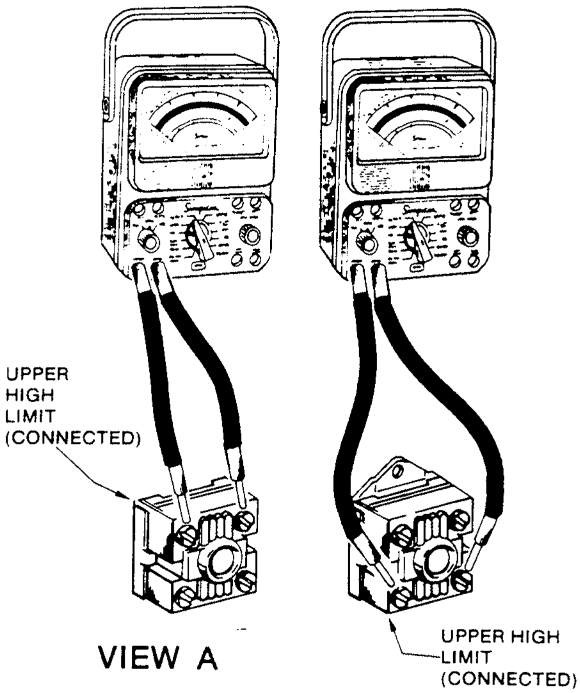


Figure 2-25

POWER CHECKS OF UPPER HIGH-LIMIT CONTROL

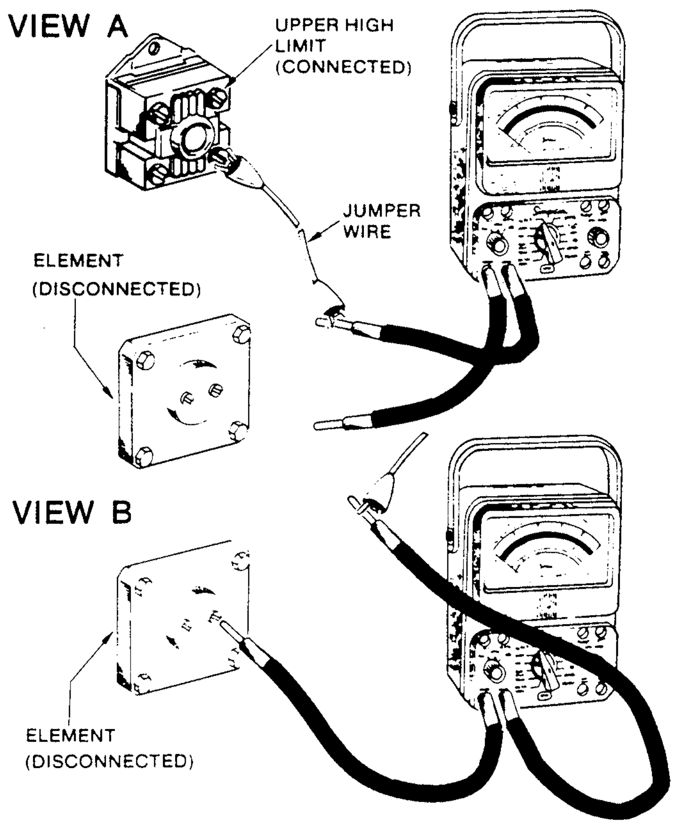


Figure 2-26

GROUND CHECK OF UPPER HIGH-LIMIT CONTROL

element is not grounded and should be tested for continuity.

.24 **Continuity Check.** Lack of continuity indicates an open circuit in the element(s). Check elements for continuity as follows:

a. Attach the end of the jumper wire to either terminal of the element. (See Figure 2-27A.)

b. Turn on the power and place one of the test leads on the unused element terminal. Place the other lead on an element flange bolt. (See Figure 2-27B.)

c. Full voltage indicates the element has continuity and should heat water. (See Section 274.25.) No voltage indicates the element is defective and must be replaced.

d. Turn off the power, remove meter lead and jumper wire. Reconnect or replace elements as indicated by ground and continuity checks.

If element testing does not reveal the cause of the problem, the thermostats may be at fault.

.25 **Blown Fuses.** If the elements pass the ground and continuity checks but the heater blows fuses, it may indicate a shorted element. Check as follows:

a. Disconnect the elements one at a time, applying power to first one element and then to the other. The

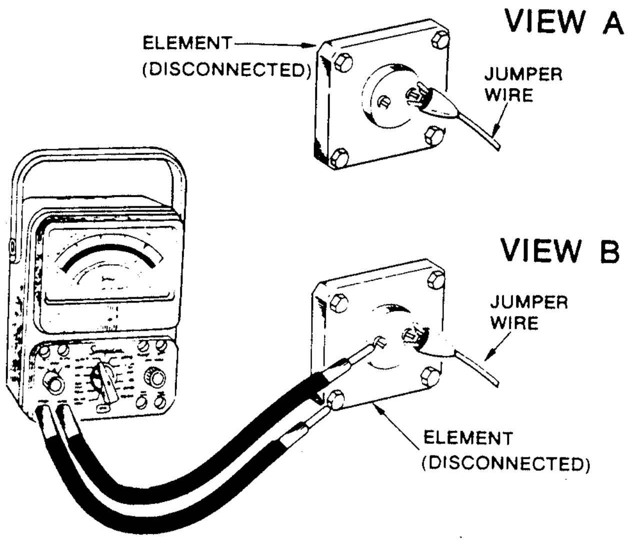


Figure 2-27

CONTINUITY CHECK OF HEATING ELEMENTS

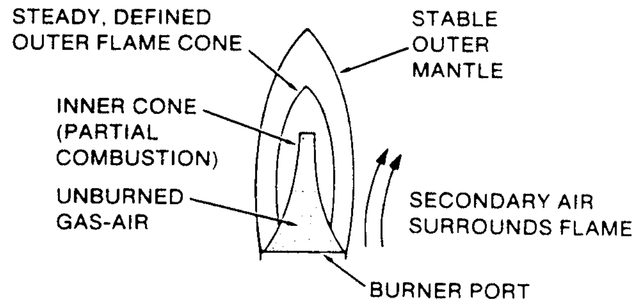


Figure 2-28

NORMAL COLOR ZONES OF BUNSEN-TYPE FLAME

element which causes the fuse to blow may be considered shorted and should be replaced.

b. Be sure the insulation on wires associated with the fuse-blowing element is good and not frayed, broken, or allowing the wire to touch grounded metal parts.

274.3 **Burner and Flame Guidelines**

.31 **Flames.** The normal color zones (see Figure 2-28) of a Bunsen-type flame are as follows:

a. A thin, blue inner cone within which is a darker area of unburned gas-air (This represents the first step in the burning process.)

b. A darker, outer flame cone which surrounds the inner cones

c. A nearly invisible outer mantle which surrounds the flame cone

NOTE

LP-gas burners have a blue-orange color flame. The outer mantle tips have a slight yellow tinge. This is a normal characteristic.

.32 **Burners.** The main burner should display the following operating characteristics: (1) complete combustion of gas; (2) rapid ignition and carryover of flame across entire burner; (3) quiet operation during ignition, burning, and extinction; (4) no excessive lifting of flames from burner ports; and (5) uniform heat spread over the bottom head of the tank. Check gas input and then reduce primary air, if necessary, and if it is adjustable. When reducing primary air, make sure yellow flame tips do not occur. Check the burner orifice size.

274.4 Typical Tank Water Heater Burner Problems

The following is a list that may help to identify and solve some typical problems in tank water heaters:

a. Explosive Combustion. Explosive combustion usually results from delayed ignition (a collection of air and gas) and indicates adjustments are necessary. Do not allow unburned gas to collect in combustion chambers or confined spaces because a gas-air mixture within flammability limits explodes if ignited.

b. Yellow Flame. Incomplete combustion can produce carbon monoxide, causing soot buildup and product damage. Check for:

(1) Restricted airflow into heater, caused by secondary air openings and/or poor venting.

(2) Inadequate air supply into heater area.

c. Lifting Burner Flames. This happens when flames lift or burn some distance above the port. Flame cones may rupture, and complete burning does not take place. Lifting (blowing) flames are noisy, form carbon monoxide and reduce efficiency (unburned gas escapes). (See Figure 2-29.)

d. Flashback. Flashback is a condition where the inner flame cone is inverted. The flame strikes back through the port to ignite the mixture in the burner head near the orifice. Burning in the mixer tube usually creates a roaring noise like a blowtorch. Flashback can occur on flame ignition or extinction although it is more likely to occur on a hot burner. Flashbacks cause carbon monoxide, soot, and burner damage. Check the following:

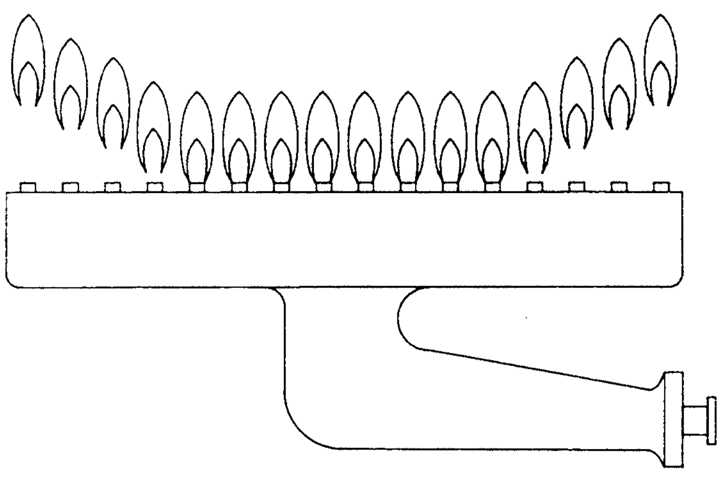


Figure 2-29

LIFTING BURNER FLAMES

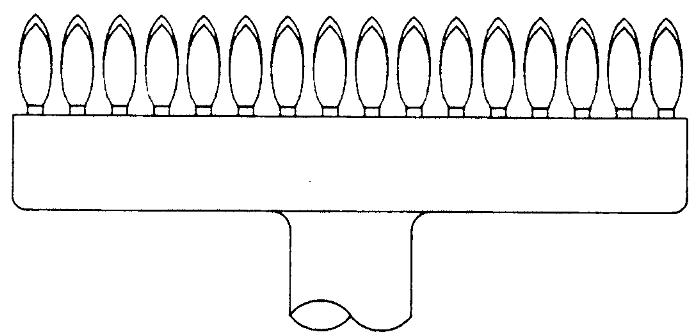


Figure 2-30

YELLOW TIPPING

(1) Decrease the primary air, if adjustable. This lowers the tendency for flashback.

(2) Determine that air adjustment does not produce yellow tipping of flames.

(3) Check the orifice size and gas pressure.

CAUTION

A leaking valve can cause burning at the orifice when the gas control has shut off.

e. Extinction Pop. Extinction pop is a form of flashback that occurs upon, or a few seconds after, shutdown. The concussion may blow out the pilot flame. Reducing the primary air, if adjustable, may eliminate the problem.

f. Yellow Tipping Flame. Yellow tips are caused by glowing carbon particles in flames. Soot and carbon monoxide form if the yellow tips impinge on cool surfaces. (See Figure 2-30.) Dust particles in the air may glow as they pass through flames. These red or orange color streaks are not a problem. True yellow tipping is eliminated by increasing the primary air (if adjustable). Dust streaks disappear when viewed through some tinted glasses such as brazing goggles. Yellow tipping, however, will not. Look for blocked air openings and lint or dust in burner tubes or underneath ports. An out-of-line, faultily drilled, or dirty orifice can also cause the problem.

g. Fluctuating Flames. This happens when the length of the flame changes over a short period of time with no readjustment of the burner. A nonuniform orifice gas pressure is usually indicated. Fluctuating flames are usually caused by gas regulator, meter, or supply. Check the orifices for cleanliness.

h. Unstable or Wavering Flames. Drafts across the burner may cause flames to waver. Incomplete burning results when flames impinge on cool surfaces. Pilot flames may go out or divert from the thermocouple, causing shutdown. Check for floor drafts.

i. Floating Flames. A lack of secondary air may cause the burner flames to float and appear hazy. Floating flames may indicate incomplete combustion and must be corrected. (See Figure 2-31.) Check the following:

(1) Secondary air supply may be restricted.

(2) Input gas pressure may be too high.

(3) Flueways may be sooted or blocked.

(4) Yellow tipping may exist and require adjustment.

NOTE

Reducing the supply of primary air will not stop floating flames. If a draft is established, floating flames may disappear after a burner operation.

j. Flame Rollout. This is where flame rolls out of combustion chamber openings when the burner goes on. This creates a fire hazard, scorched finish, and damaged wires and controls. It is a variation of floating flames as flames reach outside the combustion chamber for air. (See Figure 2-32.)

The basic cause is lack of combustion air due to the following:

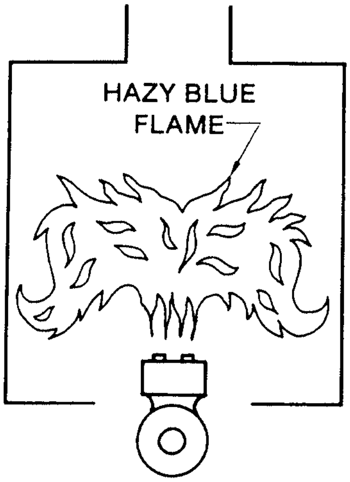


Figure 2-31
FLOATING BURNER FLAMES

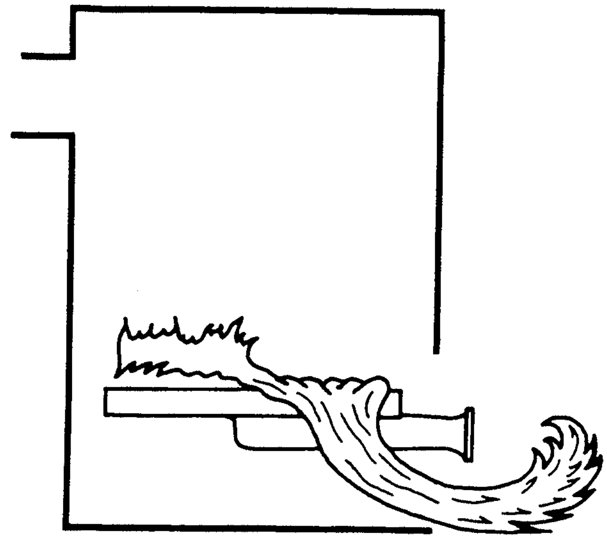


Figure 2-32
FLAME ROLLOUT

(1) Excessive gas input

(2) Poor draft

(3) Blocked flueways

Use the same corrective measures as floating flames and, if the gas valve is a step-opening type, check to see if it is operating properly.

k. Gas Odor at Primary Air Openings. To draw in air, a vacuum exists at primary air openings. If all of the gas fed to a burner by the orifice does not flow to the head, some may spill from the primary air openings. Check the burner restrictions and proper orifice alignment.

l. Very Small Pilot Flame. Usually indicates a clogged orifice or restricted pilot line. If the pilot becomes small when the main burner turns on, the pilot filter may be clogged.

m. Lazy Blue Pilot Flame. This wavy, undefined shape indicates burning at the orifice. This condition may be accompanied by high-pitched whistling sounds that also indicate a burred or partially blocked orifice.

n. Lifting, Blowing Pilot Flame. This is generally caused by high gas pressure and/or too large an orifice.

o. Hard Sharp Pilot Flame. This is usually noisy, and may blow out or backfire and burn at the orifice. It usually indicates an incorrect orifice (too small).

p. Yellow Pilot Flame Tips. This is commonly caused by a clogged pilot primary air opening (if used). Small yellow tips are normal on LP-gas.

q. Lazy Yellow (Candle Lighting) Pilot Flame. Check for low pilot gas pressure and a dirty pilot burner. Check the main burner orifice to determine it is not too large (this would create high combustion chamber temperature).

r. Pilot Flame Pulled Away from Thermocouple. This happens when secondary air rushes across the pilot burner (usually during main burner shut-off) and extinguishes the flame. A sample preventive maintenance checklist for electric water heaters is shown in Exhibit 2-6A and gas water heaters in Exhibit 2-6B, Appendix C.

275 POINT-OF-USE WATER HEATERS

275.1 General

In conventional post office water heater installations, the water heater is some distance from the actual point of water use. Additionally, because of the time required to heat cold supply water entering the tank, the water heater is designed to store water in anticipation of use. The water heater supplies the hot water tap via insulated pipes. With the advent of energy shortages and high energy costs, new methods of water heating were introduced. Point-of-use

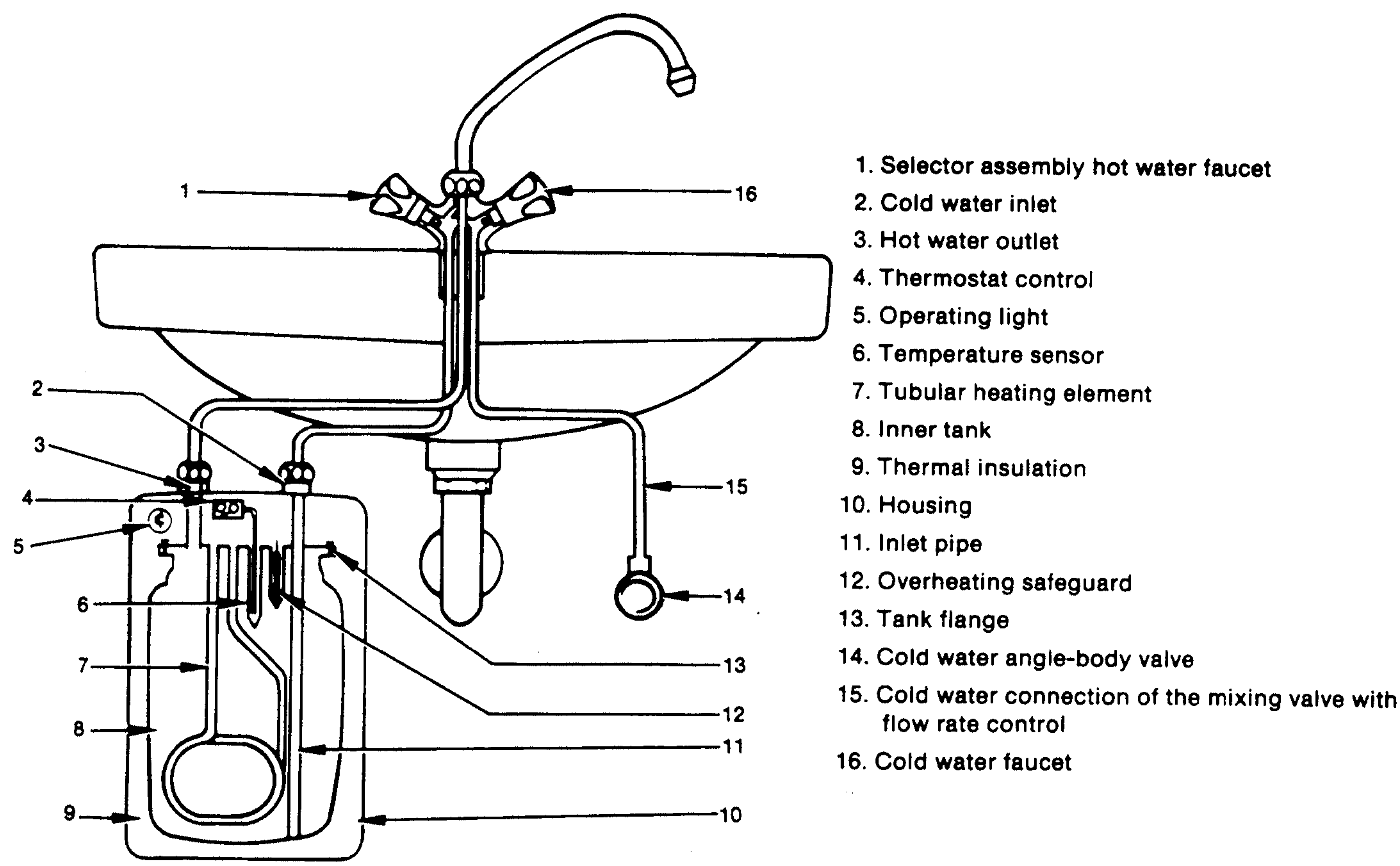


Figure 2-33

TYPICAL SINGLE BASIN INSTALLATION

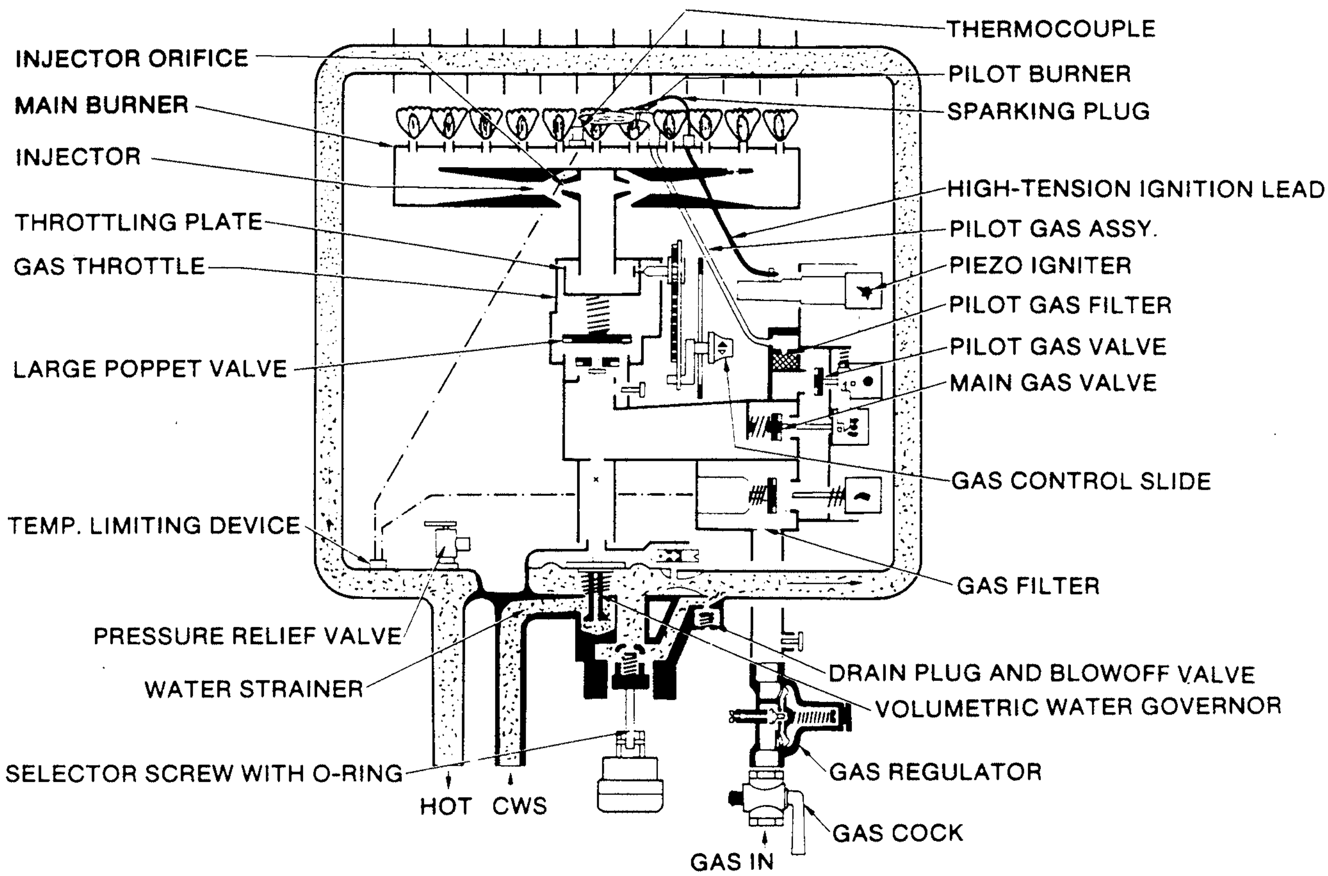


Figure 2-34

GAS-FIRED POINT-OF-USE WATER HEATER

water heaters, many styles of which have been in common use in Europe, have gained acceptance and have been recommended for installation in postal facilities. These units may use gas or electric power to provide instantaneous heating of supply water and are located as close to the actual point of water use as possible. Though not considered cost-effective on a retrofit basis, point-of-use water heaters are being installed during construction of new postal facilities. The following sizing criteria are used to determine size selection. One to two basins, use 2.5-gallon unit; two to four basins, use 5-gallon unit; each janitorial sink uses an 8- to 10-gallon unit. (See Figure 2-33 for typical single basin installation.)

275.2 Operating and Maintenance Guidelines

Point-of-use water heaters use either gas or electricity. They gain their efficiency and instantaneous heating capabilities by heating only a small volume of water. The same general maintenance practices used with tank-type heaters are used with these units. Figure 2-34 shows the construction details of a gas-powered unit. Because of the diversity of types and construction, individual manufacturer's maintenance instructions should be followed in formulating preventive maintenance checklists.

280 AIR CLEANERS AND FILTERS

281 GENERAL

The interiors of some postal facilities may require special air filtration equipment to remove contaminants from the air. Conventional air filters, such as those found on forced-air furnaces or in air-handlers, remove only 10-20 percent of these contaminants. Due to the significant amounts of cigarette smoke, swing rooms and cafeterias are examples of areas where this equipment is installed. Welding areas also generate significant amounts of smoke and odor, as do the packaging operations associated with rewrap activities. Some mail processing equipment such as sack sorters and sack shakeout machines also have either built-in or associated air-cleaning/dust-collection equipment. Commonly used dust-collection systems fall into three categories: Wet systems, where air is passed through a water spray; dry media systems, where air is passed through multiple filters; and electrostatic systems, where air is passed between electrically charged plates.

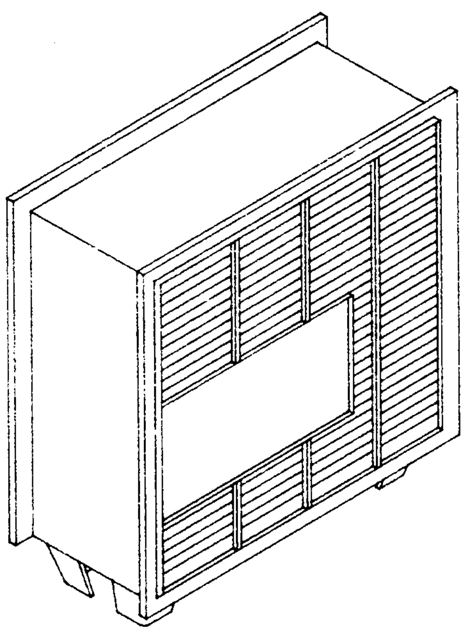


Figure 2-35
WET-TYPE AIR CLEANER

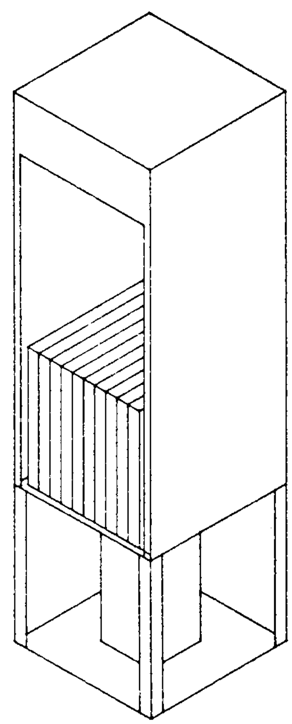


Figure 2-36
MEDIA-TYPE AIR CLEANER

282 WET SYSTEMS

A wet-type air cleaner or dust-collection system provides a high level of dust filtration by passing contaminated air through a chamber containing a water spray. The water molecules inside the chamber capture the dust particles and remove them from the air. Since water is heavier than air, these units are installed with drains that allow the contaminated water and dust solution to continuously travel down to a sanitary sewer while the unit is in operation. These units are used where very large quantities of air must be filtered. See Figure 2-35 for an illustration of this type system. A sample preventive maintenance checklist for these units is shown in Exhibit 2-7 (Appendix C).

283 DRY-MEDIA SYSTEMS

Dry-media-type air cleaners use cleanable filter elements to remove dust from air passed through multiple filters. Often these filters are a cloth material which when vibrated allows the dust to fall off into storage containers. Figure 2-36 shows a typical dry-media-type air cleaner. A sample preventive maintenance checklist for these units is shown in Exhibit 2-8 (Appendix C).

284 ELECTROSTATIC SYSTEMS

Electrostatic air cleaners create a static electrical field that electrostatically charges dust particles in the air. The particles then pass collector plates with an opposite

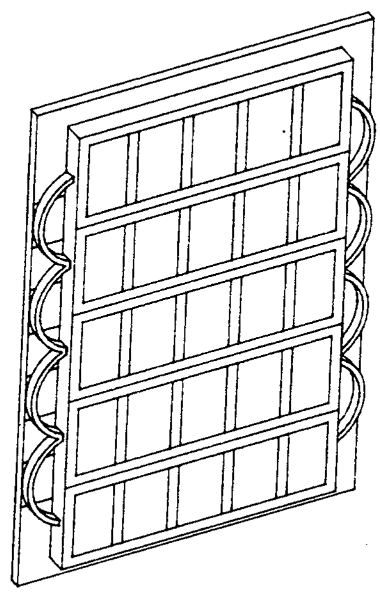


Figure 2-37
ELECTROSTATIC AIR CLEANER

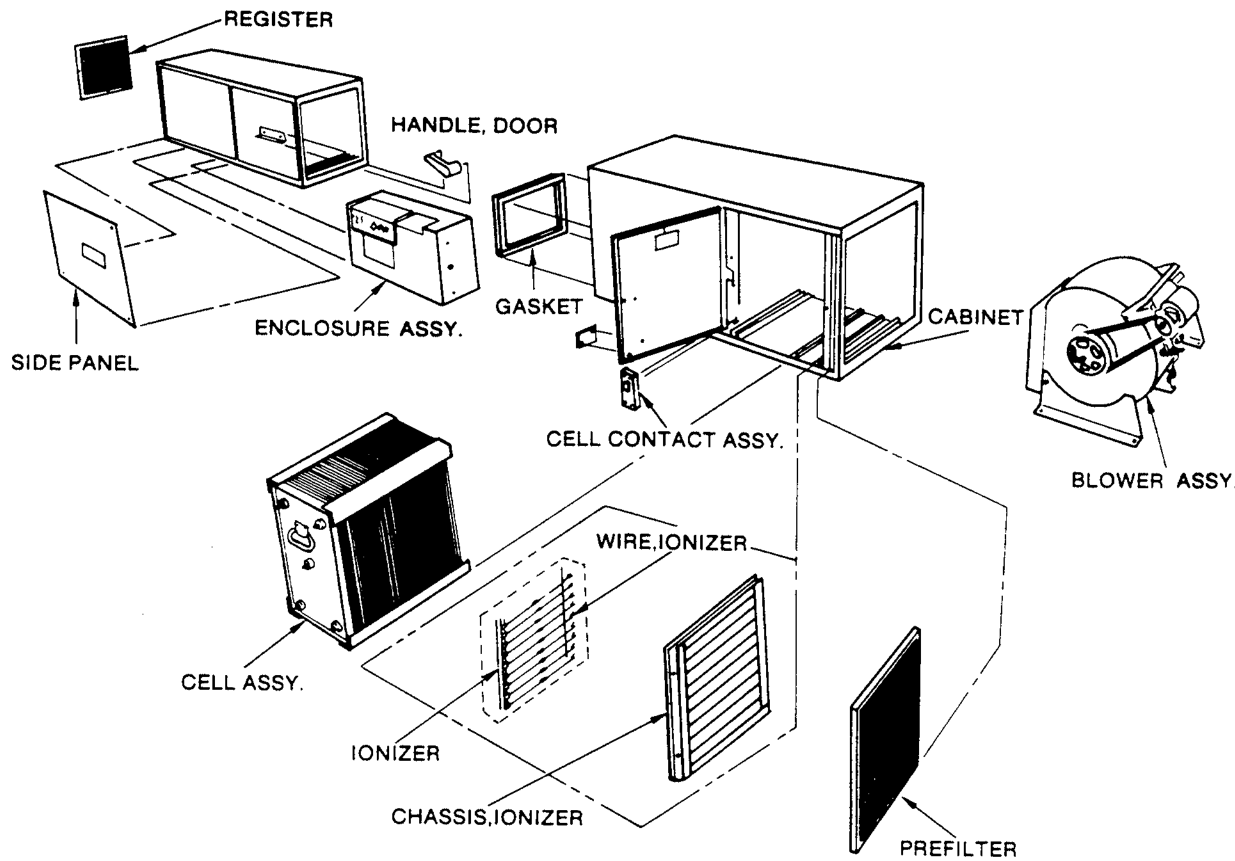


Figure 2-38
TYPICAL INTERNAL DETAILS OF ELECTROSTATIC SYSTEM

electrical charge and are attracted by the opposite charge so that they cling to the plate. These units may also be equipped with charcoal filters that remove odors from the air. These air cleaners can be installed as self-contained units or may be installed in air distribution return ducts as shown in Figure 2-37. Figure 2-38 shows the typical internal details of an electrostatic system. A sample preventive maintenance checklist for these units is shown in Exhibit 2-9 (Appendix C).

WARNING

Before working on any electrostatic unit, ensure that the unit has been given 3 to 5 minutes to discharge. A further precaution may be taken by testing the high-voltage section with a grounding wire.

285 MAINTENANCE GUIDELINES

285.1 Required Filtration

Dust collection or air filtration should be provided where activities expose employees to an 8-hour time-weighted average of total dust concentration of 15mg/M^3 or a respirable fraction average of 5mg/M^3. Per OSHA 1910-1000, General Industry Safety and Health Standards (29CFR 1910), tests to determine if dust collection is necessary should be conducted by a qualified environmental test laboratory.

285.2 Automatic Controls

All dust collection and filtration units require regular maintenance for optimum performance. However, special care should be taken to ensure that automatic controls, which provide periodic cleaning of the filter elements, are maintained in an automatic mode of operation.

285.3 Blowers

Particular care should be taken in cleaning blowers. Small buildup of material on fan blades can drastically reduce the unit's efficiency.

285.4 Ducts

Where units are provided with flexible inlet ducts, careful attention should be given to ensuring holes or tears in the duct are promptly patched. Leakage of the inlet duct will greatly decrease airflow at the pickup point.

CHAPTER 3

REFRIGERATION

310 THEORY

311 TRANSFER OF HEAT

The transfer of heat between substances is basic to refrigeration. This exchange is controlled by conduction, convection, or radiation and is induced mechanically or chemically.

312 PRESSURE-TEMPERATURE RELATIONSHIP

There is a direct relationship between the boiling point of a given liquid and the pressure exerted on it. Raising the pressure on a liquid raises its boiling point; lowering the pressure lowers the boiling point.

313 EVAPORATION OF BOILING LIQUIDS

In addition to the heat already applied to bring a liquid to its boiling point, more heat is required to change a liquid to vapor. In this process, the temperature of the liquid remains constant, even though there is a continued application of heat, and the temperature of the vapor remains the same as the boiling liquid. It may seem that this extra heat is being lost but the extra heat is actually being used to convert the liquid into vapor. The science of refrigeration is based on this property of evaporation and on the fact that liquids can be vaporized at any desired temperature by changing the pressure exerted on them.

314 EVAPORATION OF REFRIGERANTS

Evaporation is an important factor in allowing a liquid to take on more heat without raising its temperature. The latent heat of vaporization has to be absorbed from a source of heat. Heat can be absorbed from the surrounding air by some liquids, resulting in evaporation of the liquid. Refrigerants boil at very much lower temperatures than water does. To prevent these refrigerants from boiling and evaporating at normal surrounding temperatures, refrigerants must be contained under pressure. When the refrigerants are released from this pressure (as in the evaporator coils of a refrigeration unit), they immediately begin to boil and vaporize. The air or water surrounding the evaporator coils transfers its heat to the refrigerant continually vaporizing the liquid. The exchange of heat may be considered in another way: the refrigerant constantly draws heat from the surrounding air or water and absorbs it at a rate equal to the heat needed to maintain the evaporation process. For a transfer of heat to take place, the boiling temperature of the refrigerant, at the pressure in the evaporator, must be lower than the temperature of the surrounding air or water.

315 REFRIGERATION CYCLE

315.1 Elementary Cycle

Figure 3-1 illustrates an elementary refrigeration cycle. The refrigerant is boiled and evaporated in chamber A. The heat necessary for vaporization is taken from the surrounding air and the vaporized liquid passes through tube B to chamber C. A stream of water running over the outside of chamber C absorbs the heat taken on by the refrigerant, allowing the refrigerant to condense and become a liquid again. The water used for condensing must be as cold as the liquid refrigerant in chamber A because

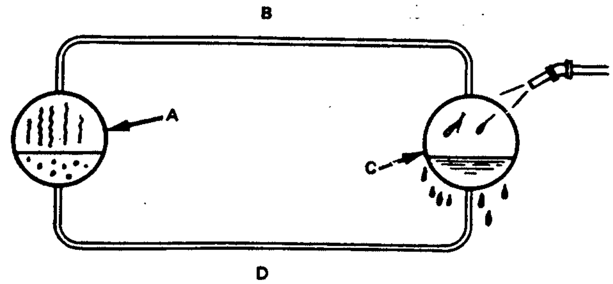


Figure 3-1
ELEMENTARY REFRIGERATION CYCLE

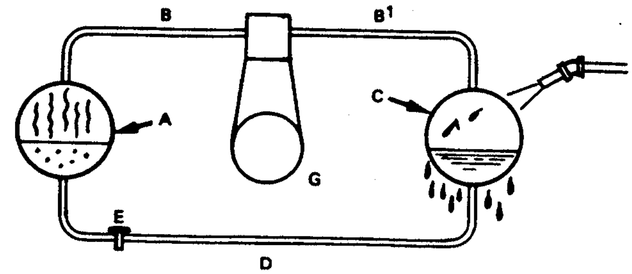


Figure 3-2
ADDITION OF COMPRESSOR TO ELEMENTARY REFRIGERATION CYCLE

the boiling point of a liquid and the condensing temperature of the vapor are exactly the same at any one pressure. The use of the cold water in chamber A, therefore, would be just as effective as the refrigerant. Some method must be applied to raise the condensing temperature of the refrigerant above the normal temperature of available water or air.

315.2 Application of Pressure and Compressor Function

The boiling temperature of a liquid is changed by applying pressure. For example, the primary concern in making a simple refrigeration cycle workable is raising the pressure in chamber C to the point where the condensing temperature of the refrigerant entering it will be greater than the temperature of the water sprayed over the outside of the container. In this way, heat can be surrendered from the refrigerant to the water. This involves the introduction of a pressure-producing device, or a compressor, into the system. Figure 3-2 illustrates this addition. It also indicates the need of an expansion valve (E) to maintain the higher pressure built up by the action of the compressor (G). In this system, the evaporated refrigerant is drawn from chamber A, placed under pressure by the compressor, and delivered to chamber C with its condensing temperature raised high enough so that water or air passing over chamber C can condense the refrigerant to a liquid. The refrigerant then flows along line D to be metered by the expansion valve into the evaporation chamber, thus renewing the cycle.

315.3 Reciprocating Compressor

The reciprocating compressor pumps refrigerant vapor from the evaporator to the condenser using a piston-type of arrangement that compresses the low-temperature gas, thus raising the pressure and temperature. The high-temperature vapor containing the absorbed heat from the evaporator is discharged to the condenser where it flows from the hot vapor into the water or air passing through the condenser.

315.4 Centrifugal Compressor

This system is identical to one employing the reciprocating compressor, but the means of compressing the refrigerant vapor is different. The centrifugal compressor has a rotating impeller that imparts a high velocity to

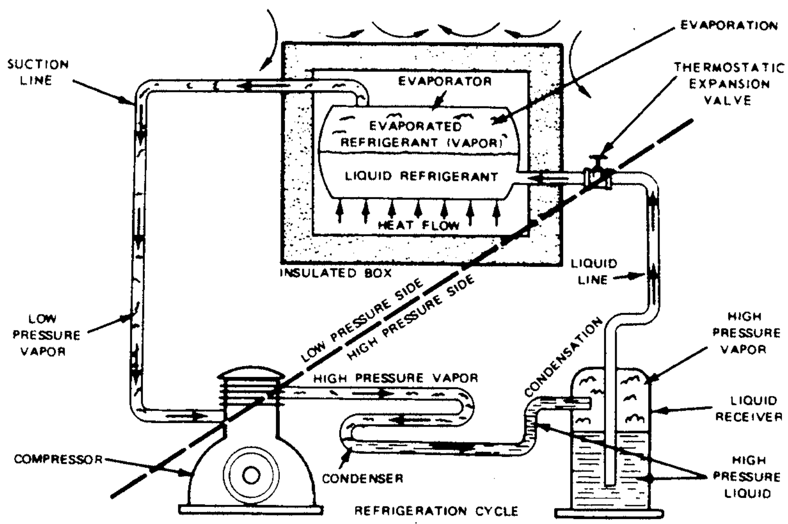


Figure 3-3

LOW-PRESSURE AND HIGH-PRESSURE SECTIONS OF SIMPLE REFRIGERATION CYCLE

the refrigerant vapor, discharging it into a smaller space, and increasing the pressure.

315.5 High- And Low-Pressure Separation

Pressure in the refrigeration cycle (or system) is divided into two parts. From the expansion valve through the evaporator to the compressor is the low-pressure section. From the compressor through the condenser and back to the expansion valve is the high-pressure section. Figure 3-3, which shows a simple schematic of a refrigeration system, illustrates this division.

320 REFRIGERANTS

321 DEFINITION AND THEORY

Refrigerants are liquid chemical compounds which, during their cycle, absorb heat, vaporize at a low temperature and pressure, give up heat, and condense into a liquid at a higher temperature and pressure.

322 REFRIGERANT PROPERTIES

322.1 Thermodynamic Properties

Thermodynamic properties are those conce ned with the relationship of heat and work. The thermodynamic properties of a refrigerant that apply the refrigeration process are pressure, temperature, density, enthalpy, and entropy. Published tables that give in detail the thermodynamic properties of the refrigerant are available from manufacturers or local dealers. Table 3-1, for example, shows the thermodynamic properties of R-12 refrigerant. To boil or evaporate R-12, the ambient temperature surrounding the refrigerant must be higher than that of the boiling refrigerant. To cause condensation, the medium must be colder than the vaporized refrigerant. Each refrigerant has a range of temperatures corresponding to definite pressures at which it will evaporate and condense. These temperature and pressure relations are found in the first two columns of the tables on each refrigerant. Since water

TABLE 3-1

PROPERTIES OF SATURATED REFRIGERANT (R-12)

TEMP °F	PRESSURE		DENSITY LB/CU FT		ENTHALPY BTU/LB			ENTROPY BTU/(LB)(°R)	TEMP °F
	PSIA	PSIG	LIQUID $1/v_f$	VAPOR $1/v_g$	LIQUID h_f	LATENT h_{fg}	VAPOR h_g	VAPOR s_g	
-40	9.3076	10.9709*	94.661	0.25806	0	72.913	72.913	0.17373	-40
-38	9.8035	9.9611*	94.469	0.27084	0.4215	72.712	73.134	0.17343	-38
-36	10.3200	8.909*	94.275	0.28411	0.8434	72.511	73.354	0.17313	-36
-34	10.858	7.814*	94.081	0.29788	1.2659	72.309	73,575	0.17285	-34
-32	11.417	6.675*	93.886	0.31216	1.6887	72.106	73.795	0.17257	-32
-30	11.999	5.490*	93.690	0.32696	2.1120	71.903	74.015	0.17229	-30
-28	12.604	4.259*	93.493	0.34231	2.5358	71.698	74.234	0.17203	-28
-26	13.233	2.979*	93.296	0.35820	2.9601	71.494	74.454	0.17177	-26
-24	13.886	1.649*	93.098	0.37466	3.3848	71.288	74.673	0.17151	-24
-22	14.564	0.270*	92.899	0.39171	3.8100	71.081	74.891	0.17126	-22
-20	15.267	0.571	92.699	0.40934	4.2357	70.874	75.110	0.17102	-20
-18	15.996	1.300	92.499	0.42758	4.6618	70.666	75.328	0.17078	-18
-16	17.653	2.057	92.298	0.44645	5.0885	70.456	75.545	0.17055	-16
-14	17.536	2.840	92.096	0.46595	5.5157	70.246	75.762	0.17032	-14
-12	18.348	3.652	91.893	0.48611	5.9434	70.036	75.979	0.17010	-12
-10	19.189	4.493	91.689	0.50693	6.3716	69.824	76.196	0.16989	-10
- 8	20.059	5.363	91.485	0.52843	6.8003	69.611	76.411	0.16967	- 8
- 6	20.960	6.264	91.280	0.55063	7.2296	69.397	76.627	0.16947	- 6
- 4	21.891	6.195	91.074	0.57354	7.6594	69.183	76.842	0.16928	- 4
- 2	22.854	8.158	90.867	0.59718	8.0898	68.967	77.057	0.16907	- 2
0	23.849	9.153	90.659	0.62156	8.5207	68.750	77.271	0.16888	0
2	24.878	10.182	90.450	0.64670	8.9522	68.533	77.485	0.16869	2
4	25.939	11.243	90.240	0.67263	9.3843	68.314	77.698	0.16851	4
6	27.036	12.340	90.030	0.69934	9.8169	68.094	77.911	0.16833	6
8	28.167	13.471	89.818	0.72687	10.250	67.873	78.123	0.16815	8
10	29.335	14.639	89.606	0.75523	10.684	67.651	78.335	0.16798	10
12	30.539	15,843	89.392	0.78443	11.118	67.428	78.546	0.16872	12
14	31.780	17.084	89.178	0.81449	11.554	67.203	78.757	0.16765	14
16	33.060	18.364	88.962	0.84544	11.989	66.977	78.966	0.16750	16
18	34.378	19.682	88.746	0.87729	12.426	66.750	79.176	0.16734	18
20	35.736	21.040	88.529	0.91006	12.863	66.522	79.385	0.76719	20
22	37.135	22.439	88.310	0.94377	13.300	66.293	79.593	0.16704	22
24	38.574	23.878	88.091	0.97843	13.739	66.061	79.800	0.16690	24
26	40.056	25.360	87.870	1.0141	14.178	65.829	80.007	0.16676	26
28	41.580	26.884	87.649	1.0507	14.618	65.596	80.214	0.16662	28
30	43.148	28.452	87.426	1.0884	15.058	65.361	80.419	0.16648	30
32	44.760	30.064	87.202	1.1271	15.500	65.124	80.624	0.16635	32
34	46.417	31.721	86.977	1.1668	15.942	64.886	80.828	0.16622	34
36	48.120	33.424	86.751	1.2077	16.384	64.647	81.031	0.16610	36
38	49.870	35.174	86.524	1.2496	16.828	64.406	81.234	0.16598	38
40	51.667	36.971	86.296	1.2927	17.273	64.163	81.436	0.16586	40
42	53.513	38.817	86.066	1.3369	17.718	63.919	81.637	0.16574	42
44	55.407	40.711	86.836	1.3823	18.164	63.673	81.837	0.16562	44
46	57.352	42.656	85.604	1.4289	18.611	63.426	82.037	0.16551	46
48	59.347	44.651	85.371	1.4768	19.059	63.177	82.236	0.16540	48
50	61.394	46.698	85.136	1.5258	19.507	62.926	82.433	0.16530	50
52	63.494	48.798	84.900	1.5762	19.957	62.673	82.630	0.16519	52
54	65.646	50.950	84.663	1.6278	20.408	62.418	82.827	0.16509	54
56	67.853	53.157	84.425	1.6808	20.859	62.162	83.021	0.16499	56
58	70.115	55.419	84.185	1.7352	21.312	61.903	83.215	0.16489	58
60	72.433	57.737	83.944	1.7909	21.766	61.643	83.409	0.16479	60
62	74.807	60.111	83.701	1.8480	22.221	61.380	83.601	0.16470	62
64	77.239	62.543	83.457	1.9077	22.676	61.116	83.792	0.16460	64
66	79.729	65.033	83.212	1.9666	23.133	60.849	83.982	0.16451	66
68	82.279	67.583	82.965	2.0282	23.591	60.580	84.171	0.16442	68

*Inches of Mercury Below One Atmosphere

is the most commonly used condensing agent, a refrigerant that will liquefy at the local water temperatures must be used.

322.2 Physical Properties

.21 **Definition.** Physical properties are the refrigerant properties that do not contribute to the ability of the refrigerant to absorb or move heat. Physical properties influence the selection of a particular refrigerant for a particular system.

.22 **Moisture.** Refrigerants absorb moisture in varying quantities. As a general rule, moisture should be kept out of the refrigeration system as moisture can freeze out the "free" water at low-temperature points in the system. This stops up metering devices, floats, etc., and shuts down the system. Moisture also contributes to the formation of corrosive acids, causing sludge, copper plating, and general deterioration within the system. Refrigerants of the hydrocarbon group absorb very little water, as do halogenated hydrocarbons. (See Section 327.2.) Both freezing of free water and acid formation take place in these refrigerants.

.23 **Leak Detection.** The refrigerant system must be free of leaks to prevent the introduction of moisture into the system and any leaks that occur must be detected and repaired. Two effective methods of leak detection are the immersion test and the soap solution test. In the immersion test, the suspected part is placed under refrigerant or dry-air pressure and then immersed in water. A leak is indicated by air escaping and bubbling to the surface. In the soap solution test, a strong soap solution is brushed over the suspected area. Any leak will be evident by the formation of bubbles in the soap solution. Both of these tests can be used for all refrigerants under a positive pressure.

Two methods of leak detection for use with ammonia are the sulphur stick and the wet litmus paper. A burning sulphur stick in the presence of ammonia will emit a white smoke. The closer the stick comes to the leak, the whiter and more dense the smoke. As ammonia is alkaline, the litmus paper will turn blue in the presence of ammonia. To test for a sulphur dioxide leak, use aqueous ammonia that emits white smoke as the two chemicals combine. Leakage of halogenated hydrocarbons is detected with a halide torch. A blue or colorless flame will turn a bright green in the presence of any of the halogenated hydrocarbons. Halogenated hydrocarbon leaks can also be detected by electronic means.

WARNING

When using the halide torch in testing for methyl chloride leak, care must be taken to ensure adequate ventilation.

.24 **Lubrication.** The ability of a refrigerant to mix with oil is called miscibility. It is a physical property that makes it easy to lubricate the refrigeration system. Most of the refrigerants in common use are miscible with oil. Ammonia, sulphur dioxide, and water are not miscible with oil.

323 TYPICAL REFRIGERANTS

There are many refrigerants. In past years, the most commonly used were air (R-729), ammonia (R-717), sulphur dioxide (R-764), carbon dioxide (R-744), methyl chloride (R-40), methylene chloride (R-30), and ethane (R-170). At present, fluorinated hydrocarbon (also known as halogenated hydrocarbon) refrigerants are being used almost exclusively in refrigerating systems. The designation of refrigerants used by the industry is "Refrigerant" or the letter "R" followed by an appropriate number. The common halogenated hydrocarbons are trichloromonofluoromethane (R-11), dichlorodifluoromethane (R-12), and monochlorodifluoromethane (R-22). R-12 and R-22 are good refrigerants for air-conditioning. They operate at moderate pressures and are easily handled. Most halogenated hydrocarbons mix easily with lubricating oils. Because of differences in boiling point and other properties, these refrigerants have somewhat different applications. Typical refrigerants are listed in Table 3-2, which includes cylinder color codes and boiling points for common refrigerants. Table 3-3 shows the vapor pressure of some refrigerants at various temperatures.

324 HARMFUL MATTER

Many of the difficulties that occur in refrigerating systems are caused by dirt and other foreign particles in the refrigerant. This foreign matter is carried through the pipelines by the refrigerant and, if it reaches the solenoid or expansion valves, it prevents them from closing, or clogs orifices and valve seats. To prevent this, a strainer may be installed in the liquid line ahead of both the solenoid and thermal-expansion valves. Large installations are often equipped with purging systems for removal of moisture by means of a dehydrator or filter arrangement that contains a drying agent.

325 MIXING OR CHANGING REFRIGERANTS

When charging any system, it is important that the equipment manufacturer's recommendation concerning the proper refrigerant be followed. Use of the incorrect refrigerant can create severe motor overloading and explosive conditions. For example, when methyl chloride is used in a system containing aluminum, or when ammonia is used in a system containing copper, chemical reactions take place that can create explosions and fire. Mixing of refrigerants creates pressure and temperature conditions that do not accomplish the refrigeration required and confuse the operating or servicing personnel.

326 SELECTION OF REFRIGERANTS

Every refrigerant has characteristics that suit it for use in certain types of refrigerating units. Certain refrigerant properties must be considered in connection with a particular installation: evaporator pressures; air leakage into system; heat conductivity; corrosiveness to materials in the system; leakage tendencies; and effect on the lubricant. The type of compressor largely determines the choice of refrigerant. Reciprocating compressors work most efficiently on refrigerants with high vapor pressures and boiling points below 30 °F. Rotary and centrifugal compressors require refrigerants with low vapor pressures. In centrifugal compressors, pressure is built up by high rotary speed, and large volumes of gas must be handled. Centrifugal compressors work best on refrigerants with boiling points between 30 and 90 °F; however, refrigerants with boiling points between 0 and 80 °F are suitable for rotary compressors. The ideal refrigerant should be a gas at normal temperatures, should liquefy at reasonable pressures, and should not require excessive cooling. It must have a high latent heat of evaporation per unit weight; it must expand and evaporate readily when the pressure is reduced; it must produce the required amount of refrigeration; and it must have a freezing point below the lowest temperature in the evaporator. It should also be nontoxic, nonexplosive, and harmless to the human body. It must not have an offensive odor, yet it should permit easy detection of leaks.

TABLE 3-2

REFRIGERANTS

Typical Refrigerants

Refrigerant Number	Common Name	Boiling Point °F (0 psig)
R-11	Refrigerant -11	74.9
R-12	Refrigerant -12	-21.6
R-22	Refrigerant -22	-41.4
R-30	Methylene Chloride	104.4
R-40	Methyl Chloride	-11.6
R-170	Ethane	-127.8
R-717	Ammonia	-28.0
R-718	Water	212.0
R-764	Sulphur Dioxide	14.0

Refrigerant Cylinder Color-Code

Refrigerant	Cylinder Color
R-11	Orange
R-12	White
R-22	Green

Operating Pressures for the Common Fluorinated Hydrocarbons

	Suction	Discharge
R-11	14.3 in Hg.	3.6 psig
R-12	40.7 psig	93.2 psig
R-22	74.5 psig	159.8 psig

TABLE 3-3

PRESSURE TEMPERATURE CHART
VAPOR PRESSURE-PSIG

TEMP °F	REFRIGERANT 11	12	22	113	114
-50	28.9*	15.4*	6.1*	- - -	27.2*
-45	28.7*	13.3*	2.7*	- - -	26.7*
-40	28.4*	10.9*	0.6	- - -	26.1*
-35	28.4*	8.3*	2.6	- - -	25.5*
-30	28.1*	5.5*	4.9	29.3*	24.7*
-25	27.4*	2.3*	7.4	29.2*	23.9*
-20	27.0*	0.6*	10.2	29.0*	22.9*
-15	26.5*	2.5	13.2	28.9*	21.8*
-10	26.0*	4.5	16.6	28.7*	20.6*
- 5	25.4*	6.8	20.2	28.4*	19.3*
0	24.7*	9.2	24.1	28.2*	17.8*
5	24.0*	11.8	28.3	27.9*	16.1*
10	23.1*	14.7	32.9	27.5*	14.3*
15	22.1*	17.8	37.9	27.2*	12.3*
20	21.1*	21.1	43.3	26.7*	10.1*
25	19.9*	24.7	49.0	26.3*	7.6*
30	18.6*	28.5	55.2	25.7*	5.0*
35	17.2*	32.6	61.9	25.1*	2.1*
40	15.6*	37.0	69.0	24.4*	0.5
45	13.9*	41.7	76.6	23.7*	2.2
50	12.0*	46.8	84.7	22.9*	4.0

TEMP °F	REFRIGERANT 11	12	22	113	114
55	9.9*	52.1	93.3	22.0*	6.0
60	7.7*	57.8	102.4	21.0*	8.1
65	5.3*	63.9	112.2	19.8*	10.4
70	2.6*	70.3	122.5	18.6*	12.9
75	0.1	77.1	133.4	17.3*	15.5
80	1.6	84.3	145.0	15.8*	18.3
85	3.2	91.9	157.2	14.2*	21.4
90	5.0	100.0	170.0	12.5*	24.6
95	6.9	108.4	183.6	10.7*	28.0
100	8.9	117.4	197.9	8.6*	31.7
105	11.1	126.8	212.9	6.4*	35.6
110	13.4	136.7	228.6	4.1*	39.7
115	15.9	147.1	245.2	1.5*	44.1
120	18.5	158.0	262.5	0.6	48.7
125	21.3	169.5	280.7	2.1	53.7
130	24.3	181.5	299.7	3.6	58.8
135	27.4	194.1	319.6	5.3	64.3
140	30.8	207.2	340.3	7.0	70.1
145	34.4	221.0	362.0	8.9	76.2
150	38.1	235.4	384.6	11.0	82.6

*Inches in Mercury Vacuum

NOTE

In addition to the above characteristics, the manufacturer's recommendations should be followed in the selection of a refrigerant for a particular system.

327 DANGER OF REFRIGERANT ADDITIVES

327.1 Antifreeze

Methyl alcohol, if used as an antifreeze, can react with aluminum and cause corrosion. Without exception, experience indicates that all chemical antifreeze agents are either directly corrosive to metals or accelerate refrigerant decomposition. There is no known safe antifreeze for a refrigeration system.

327.2 Dessicants

Refrigerants of the halogenated hydrocarbon group absorb small amounts of water. Both freezing-out of the free water and acid formation take place in these refrigerants. One method of drying the system is the use of a dessicant, a chemical compound capable of removing the water. The use of an improper dessicant can create a chemical reaction that produces acid and causes corrosion. Some dessicants dust severely enough to contaminate the system. Other dessicants slake or otherwise deteriorate. In summation, the addition of antifreeze and other contaminants causes serious trouble.

328 HANDLING

Whenever refrigerants are used, adequate ventilation must be provided. The accidental discharge of large quantities of gas, even though nontoxic, can cut off the supply of air. Anyone working in areas where there is a high concentration of certain refrigerants, such as methyl chloride and ammonia, must wear an approved gas mask. When handling refrigerants with extremely low boiling points, protective equipment such as gloves, face or eye protection, and any other available equipment should be used to prevent possible frostbite.

329 REFRIGERATION OILS

329.1 Definition

Refrigeration oils are special lubricating oils for refrigerant compressors and require consideration apart from normal lubricants.

329.2 Properties

Within normal system design limits, a refrigeration oil should maintain certain properties considered necessary in other industrial lubricants. It should maintain sufficient viscosity so that it will be thick enough at high temperatures to maintain a lubricating film and to satisfactorily seal some of the refrigerant system parts. It should be fluid enough to lubricate at low temperatures. It should neither carbonize when it comes in contact with hot surfaces in the system, nor should it deposit wax when exposed to low temperatures. There should be no chemical reaction between the oil and refrigerant that might cause harmful impurities. It must be mutually soluble with the refrigerant and be able to separate quickly from the refrigerant when the oil returns from the low-pressure side to the compressor. It should contain a minimum of moisture. Ability to resist deterioration by oxidation is important in prolonging the life of the oil. It should also contain little or no corrosive acid.

329.3 Selection

Because refrigeration oils are subjected to such severe conditions, the oil selected must have the necessary environmental properties. Only straight mineral oils should be used for lubrication of refrigeration compressors. Compounded oils must never be used, as they combine chemically with some of the refrigerants to form sludge and emulsions. Well-refined naphthene-based oils are better suited for refrigeration work because they have all of the special characteristics that a refrigeration compressor oil must have. They flow better at low temperatures, produce only easily removed carbon deposits, and deposit less wax at low temperatures. Usually, the manufacturer recommends the oils most suitable for his compressor under rated conditions. It is advisable to follow the manufacturer's recommendations. Periodic laboratory analysis of oil samples from all large chillers is highly recommended.

330 ABSORPTION REFRIGERATION

331 ABSORPTION CYCLE DEFINITIONS

Before discussing the absorption-refrigeration cycle, certain terms should be defined:

a. Absorbent. A substance readily capable of taking in and retaining moisture from the atmosphere.

b. Absorber. A vessel containing liquid for absorbing refrigerant vapor.

c. Concentrator. A vessel containing a solution of absorbent and refrigerant to which heat is supplied to boil away some of the refrigerant.

d. Concentrated Solution. A solution with a large concentration of absorbent and only a small amount of dissolved refrigerant.

e. Dilute Solution. An absorbent solution, diluted by a large amount of dissolved refrigerant.

f. Condenser. A vessel in which vaporized refrigerant is liquefied by removal of heat.

g. Evaporator. A vessel in which refrigerant is vaporized to produce a refrigerating effect.

h. Heat Exchanger. A device used to transfer heat between two physically separate fluids.

i. Heat of Condensation. The heat released when a vapor condenses to a liquid.

j. Heat of Dilution. The heat released when two liquids are mixed. This is sometimes referred to as the Heat of Absorption since in the mixing process one liquid may absorb the other.

k. Sensible Heat. Heat used to raise or lower the temperature of a substance.

332 OPERATION

332.1 Theory

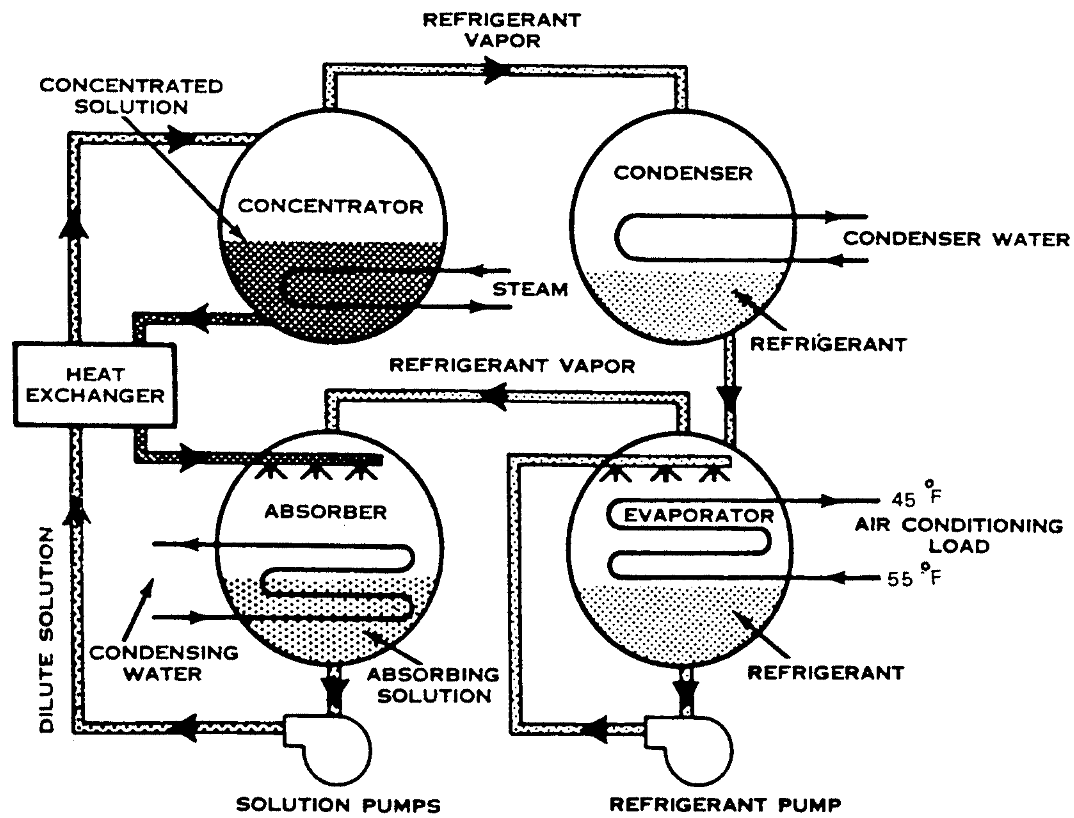
.11 Basically, absorption water-chiller operation is not too different from the more familiar mechanical-compression water-chiller. Both machines accept heat to evaporate a refrigerant at low pressure in the evaporator, and thereby create a cooling effect. Both condense the vaporous refrigerant, and a higher pressure and temperature in the condenser, in order that the refrigerant can be reused in the cycle. In both cases, the capacity of the machine depends upon the pressure that exists in the evaporator since this determines the evaporator temperature.

.12 To provide the refrigeration effect in mechanical compression systems, the vapor formed when the liquid refrigerant absorbs heat is drawn to a lower pressure area created by the mechanical movement of the pistons. In an absorption machine the vapor is also removed to a lower pressure area. However, the low-pressure area in the absorption machine is created by controlling the temperature and concentration of a water-lithium bromide solution. (See Section 332.23.)

.13 In compression systems the refrigerant vapor is mechanically compressed and moved from the low-pressure to the high-pressure side of the system. In absorption systems the vapor is first condensed and mixed into a solution of lithium bromide, then is pumped to a higher-pressure area where heat is applied. The heat causes the solution to boil, driving off the refrigerant vapor at the higher pressure. It is therefore evident that exactly the same function--that of taking low-pressure refrigerant vapor from the evaporator and delivering high-pressure refrigerant vapor to the condenser--has been performed in both the compression and absorption cycles. The only difference is in the method of transporting the vapor from the low- to the high-pressure side.

332.2 Operating Components

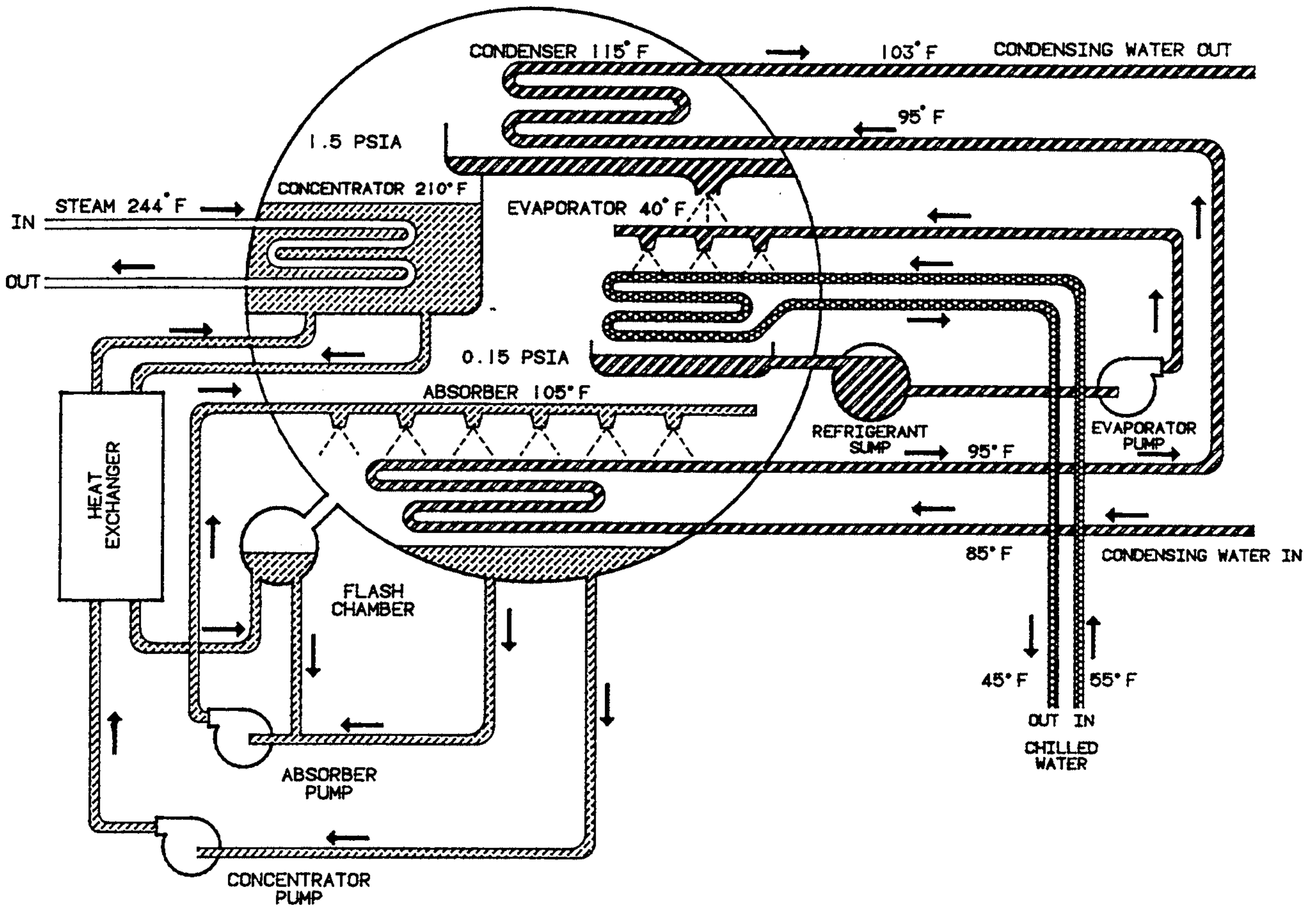
.21 **General.** The fundamental absorption cycle shown in Figure 3-4A illustrates the relationship between the main components of the absorption cycle. However, in the actual cycle the components are not lined up side by side as in Figure 3-4A. Figure 3-4A shows only



VIEW A. FLOW DIAGRAM OF ABSORPTION REFRIGERATION SYSTEM

Figure 3-4

ABSORPTION SYSTEMS



VIEW B. FLOW DIAGRAM OF ONE-SHELL ABSORPTION MACHINE

Figure 3-4

ABSORPTION SYSTEMS

how the refrigeration effect is produced and how the refrigerant and absorbent move through the cycle. Grouping the components simplifies the physical layout and arrangement of the connecting piping. To examine the components of the cycle in more detail, and to discuss certain refinements of the cycle that improve its performance, the flow diagram of a one-shell absorption unit shown in Figure 3-4B is used.

.22 **Evaporator.** Water returns from an air-conditioning system at about 55 °F, is cooled to about 45 °F in the evaporator, and is then pumped to the air-conditioning units where it picks up heat from the conditioned space. The chilled-water pump is external to the refrigeration machine and is not shown in Figure 3-4B. Liquid refrigerant in the bottom of the evaporator flows by gravity into a sump mounted on the side of the shell. The evaporator pump takes refrigerant from this sump and delivers it to spray trees in the evaporator. The spray provides a higher rate of heat transfer between the water in the tubes and the refrigerant on the outside of the tubes than tubes simply immersed in the refrigerant. This high rate of heat transfer is, of course, desirable since the purpose of the evaporator is to remove heat from the water used for air-conditioning and to thereby boil the refrigerant.

.23 **Absorber.** Because of the lower pressure in the absorber, the refrigerant vapor produced in the evaporator flows to it. This low pressure exists because the concentrated absorbent solution (lithium bromide) exerts a strong attractive force on the molecules of refrigerant (water) vapor. The molecules of refrigerant vapor condense into a liquid as they contact the molecules of the absorbent solution. The absorbent solution is sprayed into the absorber, exposes the greatest area of the solution to the molecules of refrigerant vapor, and speeds the condensing process.

In the absorber, three quantities of heat are released: The heat of condensation from vapor condensing into the absorbent; the heat of dilution as the vapor goes into solution with the absorbent; and sensible heat. In order to remove this heat and maintain a constant temperature in the absorber, the absorbent solution falls over a cooling coil after being sprayed into the absorber. Cooling water is supplied to this coil to remove the three quantities of heat from the absorber. If this heat were not removed, the temperature and pressure in the absorber would rise, and the flow from the evaporator would stop.

After falling over the cooling coil, the solution of refrigerant and absorbent drops into the bottom of the absorber shell. Noncondensable gases may be present in the refrigeration system. These gases must be removed to permit continuous operation of the machine. The surface of the solution in the bottom of the absorber is relatively quiet and noncondensable gases tend to collect in this location. These gases are then removed by a large-capacity vacuum pump, or by an auxiliary absorber and a smaller vacuum pump. Purging of these gases is tremendously important to the successful operation of the absorption refrigeration machine, regardless of whether the components are arranged into a 1-, 2-, or 3-shell design. Without proper purging the pressure in the absorber increases to a point that the flow of refrigerant vapor from the evaporator stops.

.24 **Concentrator.** A concentrator pump continually takes part of the solution from the absorber and delivers it through a heat exchanger/flash chamber combination to the concentrator. (See Section 332.26.) Here, steam coils supply heat to boil away the refrigerant from the solution leaving the concentrated absorbent in the bottom of the concentrator. The boiling away of the refrigerant from the solution while the absorbent remains in the concentrator is possible because the refrigerant has a lower boiling point than the absorbent. The concentrator is never hot enough for the absorbent to boil. As the refrigerant vapor boils away from the solution, the absorbent left in the bottom of the unit has a higher percentage of absorbent than it does refrigerant. The solution is said to be "concentrated"; hence, the name "concentrator" for this component of the machine. Hot water can also be used in the concentrator as a source of heat for the cycle.

.25 **Condenser.** The refrigerant vapor, boiling from the solution in the concentrator, flows upward to the condenser. Here, it comes into contact with coil tube surfaces filled with condenser water. The condenser piping should contain a bypass for control purposes. This permits adjustment of the water flow rate through the condenser and gives optimum condenser temperature for the most efficient operation. The refrigerant vapor condenses and drops to the bottom of the condenser from which it flows to the evaporator through a regulating orifice. This completes the operating cycle.

.26 **Heat Exchanger.** The efficiency of the cycle is substantially improved by the use of a heat exchanger external to the shell. Note that the concentrator, for a certain operation condition, has a temperature of 210 °F, whereas the temperature of the absorber is about 105 °F. The hot solution leaves the concentrator and is transferred by the heat exchanger to the lower temperature solution going to the concentrator. After passing through the heat exchanger, the concentrated solution enters the flash chamber. Here a small part of the water in the concentrated solution flashes, or evaporates, due to the lower pressure. This flashing cools the remaining solution. The flash vapors then move into the absorber, while the remaining solution flows to mix with the solution being pumped to the absorber spray tree. The use of a heat exchanger results in a twofold gain: A lower steam consumption for the same amount of refrigerant evaporated from the concentrator; and less heat to be removed from the absorber by the cooling water.

332.3 Techniques

Heat is released within the absorption machine in two places, the absorber and the condenser. Condenser water carries away this heat energy. The most economical method of using this water is shown in Figure 3-4B. The piping arrangement pumps the cooling water first through the absorber and then through the condenser. Sources of condenser water and methods of cooling it are treated in detail in Chapter 4. Water is an operating expense that should be a part of the economic survey of different refrigeration systems or the surveys conducted on the same general machine types produced by different manufacturers. In the design of some absorption machines, source and cooling are addressed by a three-way valve and control system that reduces the cooling-water requirements at partial load conditions. For example, when the unit operates at 90 percent of the refrigeration capacity, the water requirement is only 68 percent of full-load water flow. When the number of hours that a machine operates at partial load are considered, it is apparent that this control results in a significant reduction of operating costs.

332.4 Capacity Control

In an absorption machine, good capacity control is attained from 100 percent to 10 percent of full load. The machine automatically meets any changing load condition from full load down to 10 percent load. If the demand for chilled water decreases further, the machine shuts itself down. One particular control system is simple and yet completely reliable. It consists of a control element that senses the temperature of chilled water leaving the evaporator and, if it is below the set temperature, throttles the quantity of steam supplied to the concentrator. The reduced amount of steam boils a smaller quantity of refrigerant out of the solution in the concentrator. Therefore, the solution flowing from the concentrator to the absorber contains less absorbent. The solution sprayed over the tubes in the absorber is less concentrated and the ability to absorb refrigerant vapor is reduced, producing less cooling effect in the evaporator.

332.5 Application

There are no reciprocating parts on the absorption machine; the only moving parts are the solution pumps and a vacuum pump. Thus, the machine does not vibrate and operates relatively quietly. The absorption machine is lightweight and has a low floor loading factor. This makes it ideal for hospitals, hotels, apartment buildings, and office buildings. It can be placed in basements, intermediate floors, or on roofs of such buildings. In a plant that generates steam for electric power, or has steam available, air-conditioning requirements of 1000 tons or more are provided economically by combining the absorption equipment with centrifugal refrigeration equipment. Water for air-conditioning is pumped through the absorption and centrifugal equipment in series. Common designs cool the water from 60 to 47 °F in the absorption machine and from 47 to 40 °F in the centrifugal equipment. The centrifugal compressor is normally driven by a steam turbine using extracted steam at about 125 psig from a turbogenerator unit. Steam from the turbine driving the centrifugal compressor is exhausted at about 12 psig and used in the absorption machine. Such a combination of absorption and centrifugal refrigeration

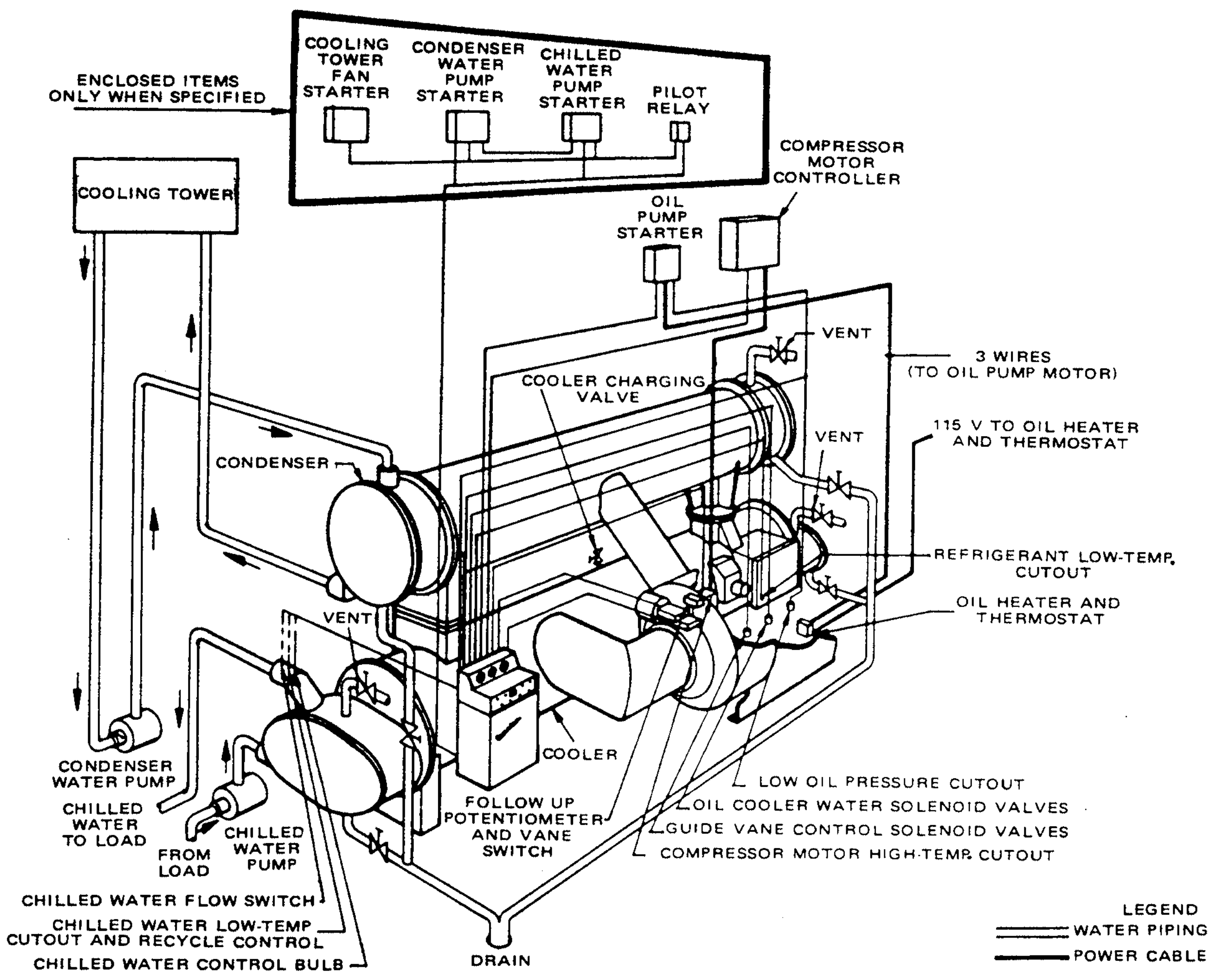


Figure 3-5

TYPICAL COMPRESSION-TYPE REFRIGERATION PLANT

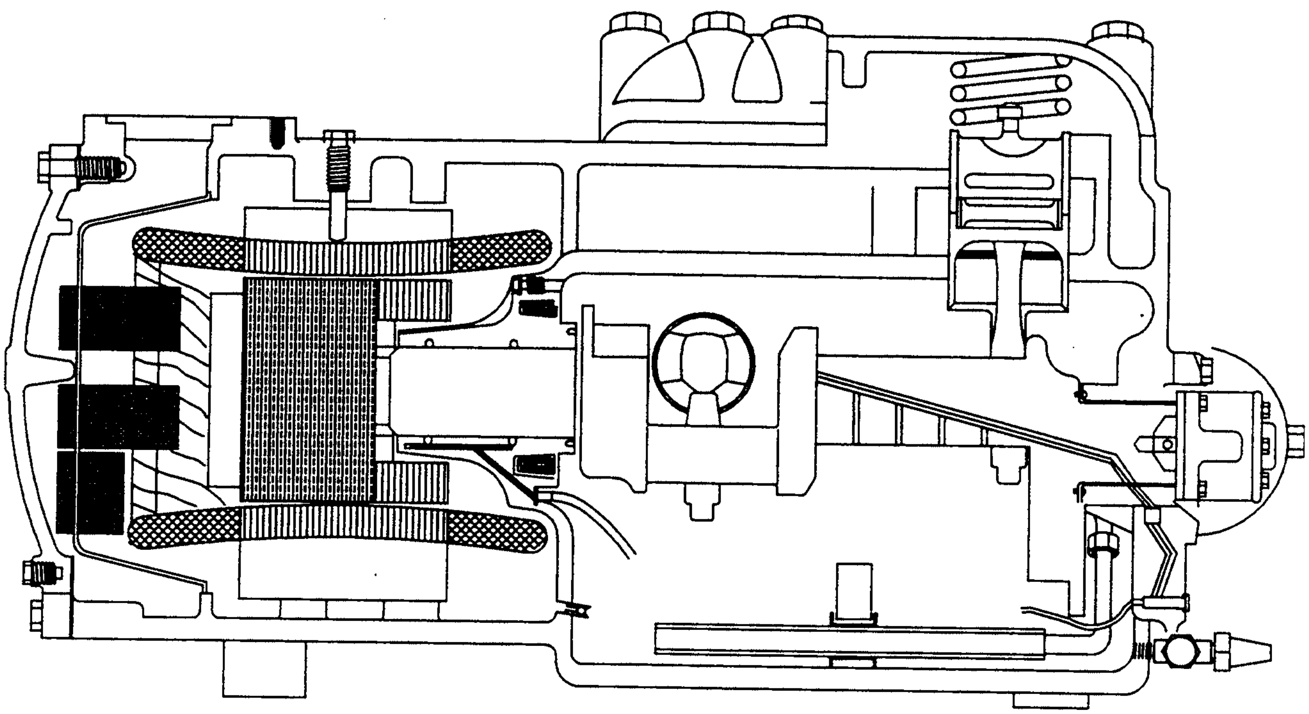


Figure 3-6
HERMETIC-TYPE RECIPROCATING COMPRESSOR

equipment has a lower operating cost than either type of equipment used singly to meet the total load.

340 CENTRAL REFRIGERATION PLANT

341 GENERAL

A given air-conditioning system may use any one of several refrigeration plants. It is the purpose of this subchapter to briefly describe some of the common refrigeration plants used in postal facilities. Figure 3-5 shows a typical compression-type refrigeration plant and indicates the various components that make up a central system and their location with respect to each other.

342 COMPONENTS

342.1 Compressors

.11 **General.** The compressor raises the pressure of the refrigerant vapor received from the chiller (or evaporator) and delivers it to the condenser, where it is condensed to a liquid.

.12 **Reciprocating.** Reciprocating compressors use cylinders, pistons, and connecting rods. (See Figure 3-6.) There are two main types of reciprocating compressors: open and hermetic. The open compressor is driven by a separate motor through an open crankshaft that extends out the end of the housing. In the hermetic-type, the motor and compressor are in the same housing and the motor is cooled by the refrigerant vapor.

.13 **Centrifugal Compressor.** The centrifugal compressor is driven by the turbine principle.

342.2 Condenser

The condenser converts the high-temperature refrigerant vapor received from the compressor to a liquid and delivers it to the thermal expansion valve ahead of the chiller as a high-pressure liquid.

342.3 Evaporator

The chiller receives the high-pressure liquid from the thermal expansion valve. By expanding in this low-pressure area, the liquid refrigerant boils, evaporates, and becomes a vapor again. Figure 3-7 shows the path of the chilled water as it leaves the chiller, how it is controlled, and how its temperature changes as it leaves the air handlers and is returned to the chiller.

342.4 Cooling Tower

In a cooling tower, the water from the tower is circulated through the condenser, then returned to the tower. After passing through the tower, it is recirculated through the condenser again. A cooling-tower system may be classed as an open system, since it is open to atmosphere at the tower.

343 MAINTENANCE CONTROLS

343.1 General

An air-conditioning load is generally subjected to considerable variation during the operating day or week, and to seasonal changes. If proper conditions are to be maintained in the building, and if operating costs are to be kept to a minimum, controlling the refrigeration equipment is required.

343.2 Reciprocating Compressor

One control is used to vary the refrigeration capacity of the system as the demand for refrigeration varies. In a reciprocating compressor, capacity is varied as follows:

a. Multispeed compressor motors

b. Multiple compressors

c. Clearance pockets

d. Cylinder cutouts

e. Cylinder ports

f. Suction-valve-lift unloaders

g. Artificial compressor loading by balance loaders and hot gas bypasses

343.3 Centrifugal System

.31 **General.** The subject of controls for centrifugal-refrigeration systems can logically be divided into capacity control methods and basic cycle controls. Various methods of accomplishing capacity control are currently being used and are listed as follows:

a. Off-and-on control

b. Hot gas bypass control

c. Condenser water regulation

d. Butterfly dampers

e. Speed control

f. Variable-inlet guide vanes

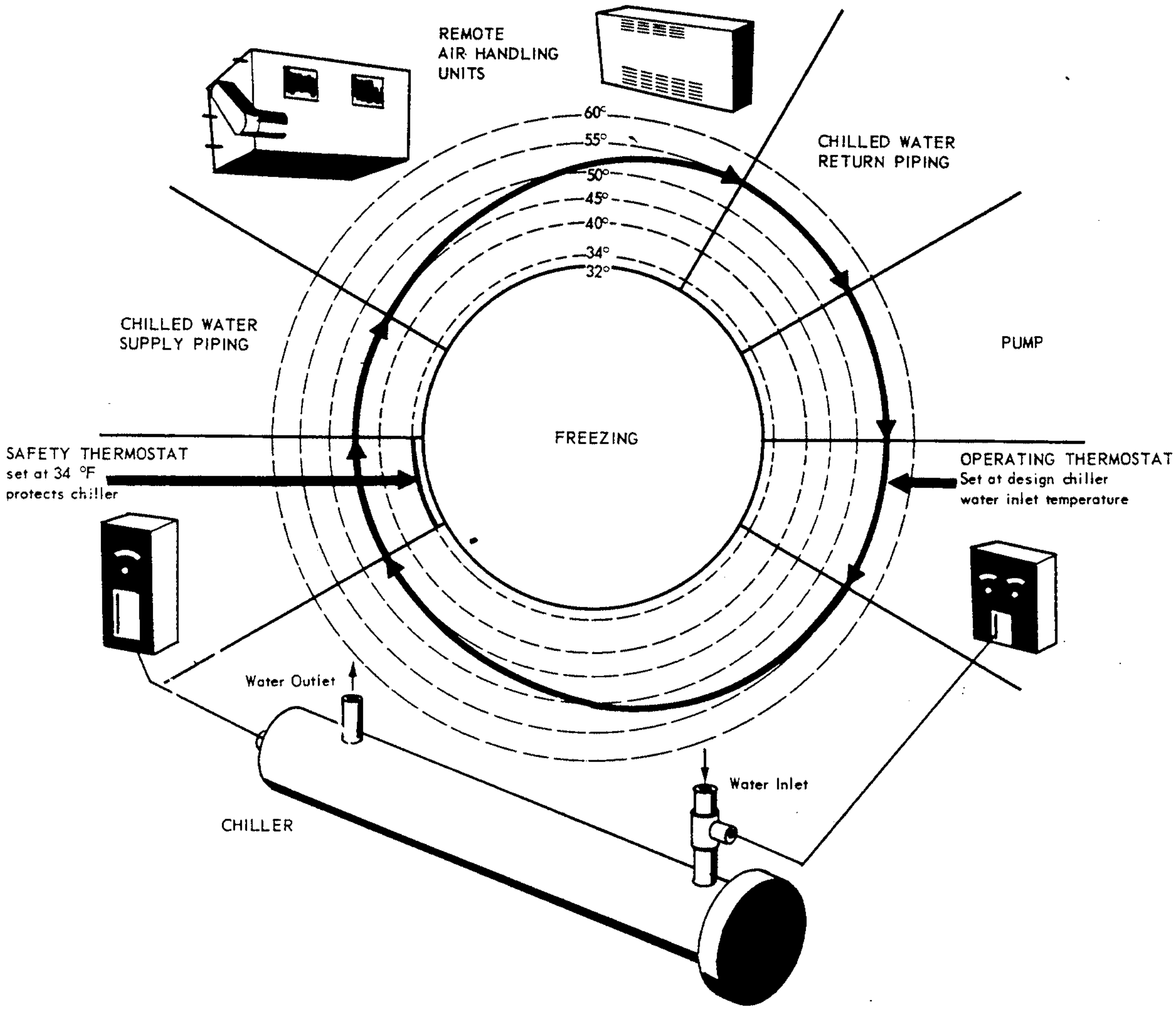


Figure 3-7

TEMPERATURE GRAPH OF COLD WATER CIRCULATING IN TYPICAL CHILLER INSTALLATION

.32 Controls. The most commonly used methods of control in postal facilities are the hot gas bypass control and the variable-inlet guide vanes. The hot gas bypass control consists of the installation of a bypass between the discharge and suction side of the compressor. When the compressor load is reduced to almost the surge point, a valve in the bypass line opens and permits high-pressure vapor from the discharge side of the compressor to enter the evaporator or suction side of the compressor. As the load is reduced further, the bypass opens wider so as to maintain a fixed minimum-volume flow rate to the compressor. Because there is no reduction in power input to the compressor once the bypass starts to open, bypass control is uneconomical.

Variable-inlet guide vanes vary capacity by changing the angle at which the suction vapor is directed into the inlet of the impeller. The variable inlet guide vane operation is discussed in Section 363.3.

The basic cycle control is a device that starts, regulates, and/or protects the refrigeration system and its components. Cycle controls are divided into two distinct categories, primary and secondary. The primary control actually starts and stops the cycle as dictated by the temperature requirements. In an air-conditioning system, the primary control is the thermostat. Secondary controls can be further divided into operating and safety controls. The operating controls include the thermal expansion valve, motor controls, valves for controlling refrigerant and water flow, back-pressure valve, and the check valve. The safety controls include protection against electrical overload, the low-temperature safety thermostat, high-pressure cutout, low-pressure control, and the oil-safety switch.

344 TROUBLESHOOTING AND PREVENTIVE MAINTENANCE GUIDE

A troubleshooting guide has been provided (see Part 363) listing the most common troubles that may occur to the refrigeration plant using centrifugal-type compressors. The guide includes the probable causes of the listed troubles and recommended remedies for the correction of the troubles. Data contained in this guide is of a general nature and is intended to provide a standard approach to identifying and analyzing the most common troubles. It is recommended that this guide be reviewed at the local level and expanded, if necessary, to include the results of local experience. While performing troubleshooting procedures, observe all normal precautions for safeguarding personnel and equipment. A sample preventive maintenance checklist for centrifugal and reciprocating unit is shown in Appendix C as Exhibit 3-1. A sample tour and a daily and weekly preventive maintenance checklist for a typical air-conditioning system are contained in Appendix C as Exhibit 3-2.

345 LOGS AND RECORDS

345.1 General

An operating record of all refrigeration machines must be kept. Usually the manufacturer includes in his maintenance manual suggested methods for preparing a log in his maintenance manual. Proper interpretation of the record ensures efficient operation of the refrigeration plant and protects it from costly breakdowns.

345.2 Reciprocating Type Refrigeration Machines

For this type of machine, use Form 4990, Operating Log for Reciprocating Refrigeration Plants. (See Exhibit 3-3,

Appendix C.) Form 4990 is available from the supply centers.

345.3 Centrifugal Refrigeration Plants

For this type of machine, use Form 4994, Operating Log for Centrifugal Refrigeration Plants. (See Exhibit 3-4, Appendix C.) Form 4994 is available from the supply centers.

346 CENTRAL REFRIGERATION MAINTENANCE

346.1 General

Proper maintenance of equipment in the central refrigeration plant is necessary to protect the health and safety of the general public and USPS employees. Furthermore, the large capital investment in this equipment makes proper maintenance of this equipment vital.

346.2 Absorption Machines

Only personnel with appropriate training and experience may work on absorption-type refrigeration machines. A sample preventive maintenance guide for use with this type of equipment is shown in HBK MS-1, Operation and Maintenance of Real Property, Section 13.

346.3 Centrifugal And Reciprocating Refrigeration Machines

Only personnel with appropriate training and experience may work on centrifugal and reciprocating refrigeration machines. HBK MS-1, Section 13, provides a preventive maintenance guideline for maintenance of these refrigeration machines. Exhibit 3-1 in Appendix C of this handbook also provides a sample checklist in a checklist format.

346.4 Cooling Towers

HBK MS-1, Section 13, provides a guideline for cooling tower preventive maintenance. Proper operation and maintenance of the cooling tower can have an impact on the operational efficiency of the entire refrigeration system. Under no circumstances may a cooling tower be modified without seeking professional advice.

347 EDDY-CURRENT TESTING

347.1 General

Eddy-current testing is a nondestructive testing procedure for evaluating the condition of tubing. A probe with an electrical coil that induces eddy currents in the tube wall is pushed through each tube. The eddy current varies with the tube wall thickness, and this variation is indicated on an oscilloscope and strip chart. Experienced, properly trained technicians can interpret the oscilloscope pattern and determine the tube wall thickness with a high degree of accuracy. The state of the internal probe nonferromagnetic eddy-current testing has advanced rapidly because of the need for increased reliability of heat exchangers used in nuclear plants, and has spread to other plants as a cost-saving maintenance procedure.

347.2 Maintenance Cycles

Maintenance cycles are as follows:

a. For locations where there is only one central chiller and failure with extended downtime would disrupt operation, eddy-current testing of both condenser and evaporator tubes must be conducted on the same 5-year cycle used to clean and inspect the evaporator. (See HBK MS-1, Section 13.) Both evaporator and condenser sections must be tested.

b. All central chillers 10 years of age and older should have eddy-current tests conducted at the next scheduled cleaning (5-year) of evaporator sections. Both evaporator and condenser sections must be tested. Thereafter, tests should be conducted on a 10-year cycle unless the tests indicate defects requiring more frequent inspection.

c. Absorption-type air-conditioning must have eddy-current tests conducted on all sections (evaporator, condenser, absorber, and concentrator) every 5 years.

d. When tube failure occurs, rather than replace all tubes (which is often done), eddy-current tests should be conducted and only the defective tubes replaced. Tubes with 30 percent or more wall thinning are normally considered candidates for replacement or isolation. This 30 percent criterion will vary with type, model, and manufacturer of equipment.

e. Special (more frequent) eddy-current tests should be conducted under the following conditions:

(1) When there is suspected damage to the tubes caused by poor water-treatment or other maintenance deficiencies.

(2) On any make or model of central chiller that is known to be prone to tube failure.

(3) When a previous eddy-current test indicated the tubewall thinning but did not require replacement or isolation.

Eddy-current tests may be conducted at more frequent intervals to determine if the tubes are continuing to deteriorate.

f. The Maintenance Technical Support Center (MTSC), Norman, Oklahoma, should be contacted for more information on eddy-current testing. Questions concerning contract specifications should also be directed to MTSC.

350 ABSORPTION PLANT

351 CONTROLS

351.1 Capacity Controls

When it senses changes in chilled-water temperature, the control system automatically throttles the quantity of steam or hot water supplied to the generator (concentrator). The capacity is modulated as required to satisfy changing system requirements. When cooling is no longer required, the unit automatically dilutes the absorbent solution before shutting down the system. This procedure prevents absorbent-solution crystallization when the solution cools to ambient temperature. The system motor starters, capacity-modulation controls, and safety devices are consolidated into a single electrically interlocked system. This arrangement ensures proper sequence of operation and provides protection against mechanical failure and improper operating procedure.

351.2 Automatic Controls

The automatic control system for the absorption machine and its auxiliary chilled-water and condenser-water pumps energizes the circuits of the solution pump, evaporator pump, purge pumps, chilled-water pump, and condenser-water pump as parallel circuits. Other controls are the purge tank liquid-level control, purged/not-purged switch, time-delay pressure switch, chilled-water low-temperature cutout, purge tank high-level cutout, and the capacity control valve.

NOTE

Since different installations may vary electrically, the system described here may not be exactly the same as that found in a particular postal installation; however, basic principles will be the same.

352 OPERATING SEQUENCE

352.1 Startup

Figure 3-8 illustrates a typical absorption chilled-water generator control arrangement. The chilled-water pump is started by pushing the START button on the pushbutton station (PB). Interlocked with the chilled-water pump starter (MS2), through a set of auxiliary motor starter contacts and a flow switch (FS) in the chilled-water circuit, are the pneumatic-electric switch (PE) and the condenser-water pump starter (MS3).

352.2 Cooling

A need for cooling, as indicated by the temperature of the chilled water leaving the unit, causes the branch-line pressure of the pneumatic chilled-water temperature control (TC1) to rise. The rising branch-line pressure closes the contacts of the pneumatic-electric switch (PE), starting the condenser-water pump through its starter (MS3).

352.3 Cooling Tower

The cooling-tower fan starter (MS4) is interlocked with the condenser-water pump starter (MS3) permitting the cooling-tower fan to start. Once started, the operation of the cooling-tower fan is cycled on and off automatically by the cooling-tower thermostat (TC3). Once the chilled-water

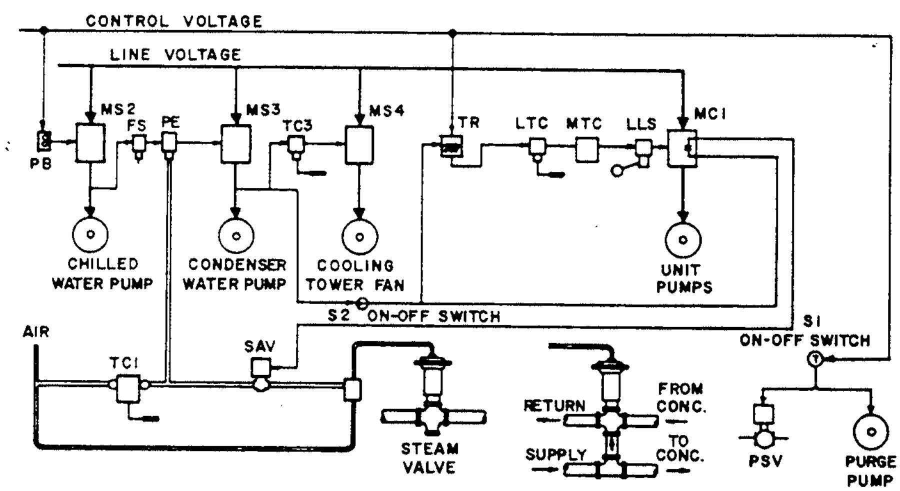


Figure 3-8

TYPICAL ABSORPTION COLD GENERATOR CONTROL ARRANGEMENT pump is started, the absorption machine can be operated. Turning the system shutoff switch (S1) to the ON position energizes the time-delay relay (TR). This supplies control voltage through the contacts of the low-temperature control (LTC), motor-temperature control (MTC), and the liquid-level switch (LLS) to the unit pump starter (MC1), which starts the unit pumps.

352.4 Solenoid

The solenoid air valve (SAV) is energized through a set of interlocking contacts in the unit pump starter (MC1). The energized air valve supplies thermostat branch-line pressure to the pneumatic-steam or hot-water valve, allowing the valve to function.

352.5 Load Control

Variations in branch-line pressure operate the pneumatic valve, controlling the flow of steam or hot water to the concentrator. This governs the rate of vaporization and concentration within the unit, enabling the absorption cold generator to hold a stable chilled-water temperature over a wide range of load conditions. When lowering chilled-water temperature, as sensed by TC1, indicates that cooling is no longer needed, the reduced branch-line pressure causes the contacts of the pneumatic-electric switch (PE) to open. This stops the condenser-water pump, which in turn deenergizes the time-delay relay (TR), the solenoid air valve (SAV), and the cooling-tower fan starter (MS4), stopping the fan. Deenergizing the SAV causes the pneumatic valve to close, stopping the flow of steam or hot water to the concentrator.

352.6 Shutdown

Prior to complete shutdown, the unit pumps under control of the time-delay relay (TR) continue to function for approximately 4 minutes, bringing about a mixing of the diluted and concentrated solutions. The temperature of the cooling water is controlled by means of a pneumatic valve installed in a cooling-tower bypass arrangement. A thermostat, sensing the temperature of the water supplied to the absorber, positions the valve to mix proper proportions of recirculated and tower water to hold the temperature of the water within design limits. The purge pump and purge solenoid valve (PSV) are energized by closing the purge ON/OFF switch (S2).

353 TROUBLESHOOTING GUIDE

Table 3-4, Troubleshooting Guide, lists the most common troubles that may occur in a refrigeration plant during the absorption process. The guide includes the probable causes of the listed troubles and recommended remedies for the correction of the troubles. Data contained in this guide is of a general nature and is intended to provide a standard approach to identifying and analyzing the most common troubles. It is recommended that this guide be reviewed at the local level and expanded, if necessary, to include the results of local experience. While performing troubleshooting procedures, observe all normal precautions for safeguarding personnel and equipment.

354 LOGS AND RECORDS

An operating log of the absorption machines must be kept. Usually the manufacturer includes a log format in his maintenance manual or in his local distributor's supply. The form records data important to the machine's operation and maintenance. Proper interpretation of this data ensures proper operation of the absorption plant and protects against costly breakdown. Exhibits 3-5 and 3-6 in Appendix C are representative of the type of log sheets available from various manufacturers. Due to the different types of absorption machines and the requirement for different factors to be checked and

TABLE 3-4

TROUBLESHOOTING GUIDE FOR ABSORPTION MACHINES

COMPLAINT	CAUSE	POSSIBLE REMEDY
1. Decreased capacity	a. Condenser and absorber tube fouling	a. Clean tubes.
	b. Noncondensables	b. Purge unit. Trace and seal possible air leak.
	c. Concentrator water or steam temperature not within prescribed limits	c. Correct water or steam temperature to comply with manufacturer's recommendations.
2. Crystallization	a. Noncondensables	a. Activate the purge unit. If purge unit operates properly, leak test the absorption unit. Make repairs as necessary.
	b. Operation with condenser water temperature lower than design temperature	b. Increase condenser water temperature.
	c. Power failure of long duration	c. Refer to manufacturer's instructions for startup of unit.
	d. Shutting machine down with insufficient dilution	d. Check operation of dilution cycle Time Delay Relay for proper operation and adjustment. Adjust or replace relay as necessary.
	e. Improper solution and water charges	e. Bring solution to proper equilibrium according to Equilibrium Chart and manufacturer's recommendations.

logged, each installation must either use a log sheet printed by the manufacturer of their equipment or develop its own log sheet using the company furnished log sheet as a guide. All log sheets developed locally should be no larger than 8-1/2" x 11" and must have regional approval before being used.

360 COMPRESSORS

361 GENERAL

The compressor pumps low-temperature, low-pressure refrigerant vapor to a higher temperature and pressure in the condenser.

362 RECIPROCATING COMPRESSORS

362.1 Description

The basic operating parts of a reciprocating compressor are a rotating crankshaft that drives a piston back and forth in a sealed cylinder and valves that admit vapor at a low pressure and discharge vapor at high pressure. In some applications, compound or multistage systems are designed to compress refrigerant vapors in two or more stages. These compressor systems are applied if refrigeration requirements are too severe for a single compressor system to handle.

362.2 Types

.21 **Open.** The open compressor (see Figure 3-9) is so-called because one end of the crankshaft extends outside the crankcase. This compressor is adaptable to a variety of drives.

.22 **Hermetic.** The motor and compressor of a hermetic compressor are enclosed in a common housing (see Figure 3-6). The compressor portion is basically the same as the open-type compressor, but the compressor and motor are connected by a common shaft inside the housing.

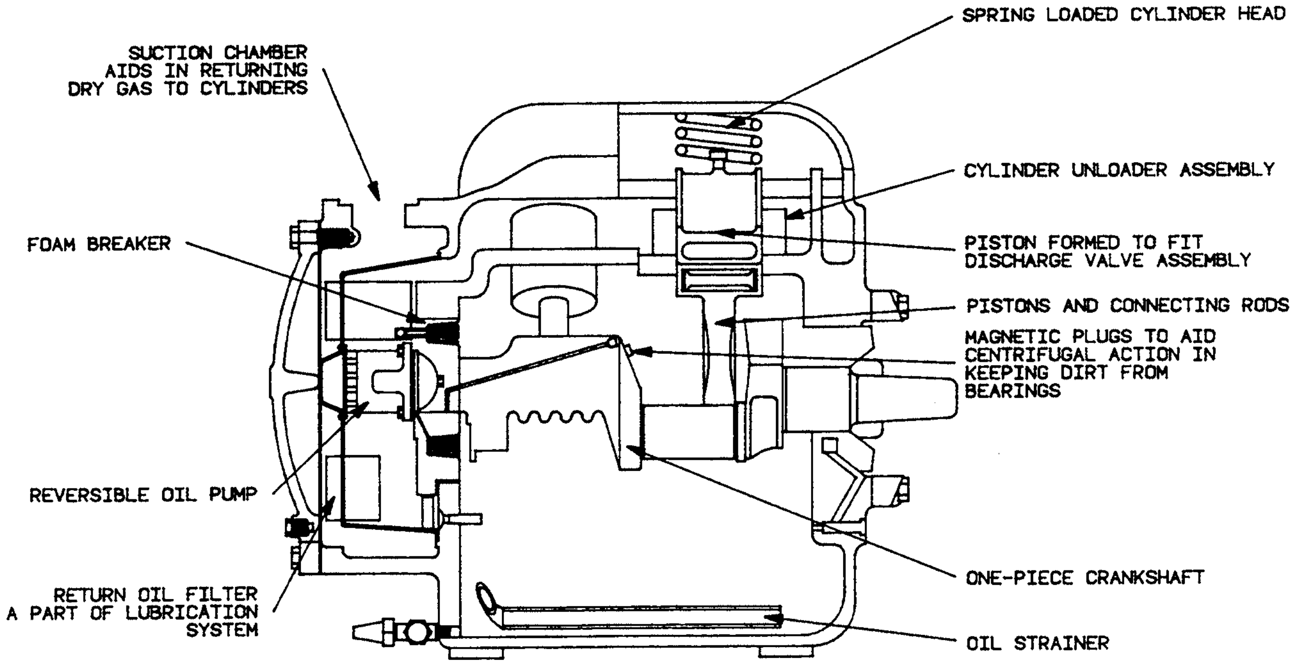
362.3 Capacity Controls

.31 **Compressor.** Capacity control is necessary because refrigeration and air-conditioning loads constantly vary. A compressor is often required to do only a part of the work for which it was designed. Four common methods of controlling compressor capacity are cylinder unloading, variable-speed motors, hot gas bypass, and cylinder bypass.

.32 **Cylinder Unloading.** Cylinder unloading means that the suction valves on the cylinders affected are mechanically held off their seats and are inoperative. The capacity control actuator (the unit which lifts and holds the suction valves off their seats) is actuated by oil pressure or an electro-mechanical device. The capacity control actuator operates because of a difference between the refrigerant-suction pressure and atmospheric pressure. If the demand for refrigeration in the evaporator decreases, the suction pressure drops and a solenoid opens. This action relieves oil pressure from the actuator valving mechanism, causing a mechanical linkage to lift the suction valve from its seat. Multiple-cylinder compressors have an unloading valve on each cylinder. As suction pressure continues to drop, the unloader mechanisms unload each cylinder in sequence until the operating cylinders have matched the load on the refrigeration system. This system is driven by a constant-speed motor.

.33 **Varying Speed.** Capacity control of the compressor is accomplished by the use of variable-speed motors or electric motors with two or more speed adjustments. The speed change can be made manually or automatically, if desired.

.34 **Hot Gas Bypass.** The hot gas bypass capacity can be controlled by



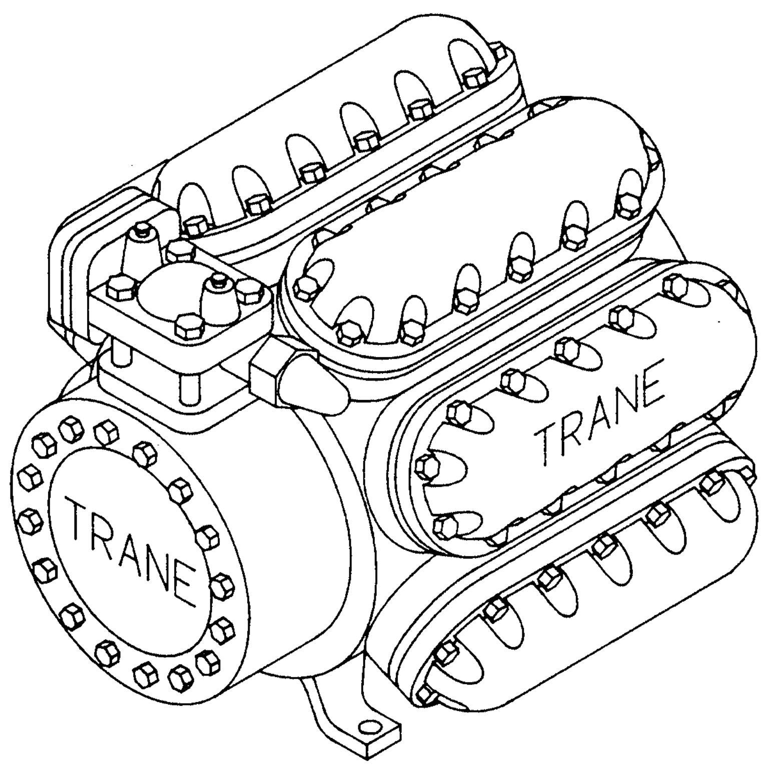


Figure 3-9

OPEN-TYPE RECIPROCATING COMPRESSOR

temperature or pressure, depending upon the type of application. As the controller calls for capacity reduction, a solenoid valve opens in a bypass line allowing some hot gas to return to the suction side of the compressor from the discharge side.

.35 **Cylinder Bypass.** The fourth method of controlling compressor capacity is the cylinder bypass system. This system is also activated by either temperature or pressure sensing. When the controller calls for capacity reduction, a solenoid opens and the discharge vapor from one block of cylinders returns to the suction side of the compressor. A check valve prevents high-pressure vapor from entering the isolated bank of cylinders. High pressure cannot be created in the bypassed cylinders, so they operate with suction pressure both above and below the valve plate and the cylinders do no work. When the system operates under partial loads, without the above listed controls, low back pressures may result in coils freezing at the evaporators.

362.4 Safety Controls

.41 **General.** Safety controls are designed to protect the components of the refrigeration system from electrical overloads, excessive temperatures, high pressure, low pressure, and loss of lubricating-oil pressure. Several types of electric switches and pressure cutouts have been developed that stop the compressor in the event of failure in some part of the system.

.42 **Excessive Current Protection.** In all electrical circuits, some kind of protection against excessive current must be provided. In motor circuits a reset-type of protector is used. When excessive current is drawn in the load circuit, this device will break the circuit, stopping the compressor. Also, in water-chilling systems, it is important that the water not be allowed to freeze and cause physical damage to the equipment. To prevent this from happening, a thermostat is used with the temperature-sensing element immersed in the water at the coldest point. The thermostat is set to break the control circuit at some temperature above the freezing point of water. This stops the compressor and prevents further lowering of water temperature and possible freezing.

.43 **Excess Pressure Protection.** Protection against excessive pressures is accomplished in several ways:

a. One way is to apply the pressure to a bellows which, as pressure increases, pushes a lever to open a set of electrical contacts, shutting off the compressor. By varying an opposing spring pressure, the pressure necessary to open the contacts can be varied, thus raising or lowering the pressure at which the compressor will shut off.

b. The relief valve is a mechanical device that protects against excessive pressures. The valve is held closed by a spring and when the vapor pressure against the valve is great enough to overcome the spring pressure, the valve opens to atmosphere, reducing the pressure. The valve automatically reseats when the pressure has been reduced to within the required limits. The fusible plug contains a core of soft metal with a low melting point. In case of fire, the soft metal melts and allows the vapor to escape to the outside atmosphere before hazardous pressures are built up. The rupture-disc fitting consists of a thin piece of metal selected to break or rupture at a pressure below that considered dangerous.

c. As a safety device, the low-pressure control is used to stop the compressor at a predetermined minimum operating pressure. This control protects against equipment damage, evaporator freeze-ups, and leakage of air into the system on the low-pressure side. A typical low-pressure control consists of a bellows connected through a capillary tube directly into the refrigerant piping at the suction manifold. As the pressure in the system changes, the pressure in the bellows changes, causing the bellows to expand or contract as the pressure varies. At a predetermined suction pressure level, the action of the bellows causes a set of electrical contacts to open, shutting off the compressor.

d. The oil-safety switch is also activated by pressure and is designed to protect against the loss of oil pressure. As the lubrication system is contained in the crankcase of the compressor, it is subjected to a suction pressure. Therefore, a pressure reading at the discharge side of the oil pump will be the sum of the actual oil pressure plus the suction pressure. The oil-safety switch measures the net pressure between the suction and discharge pressures and shuts down the compressor if the pressure goes below the predetermined net value. Thus, to guard against oil failure, the net oil pressure must be related to the suction pressure. To prevent nuisance cutouts of the compressor caused by short periods of operation at low pressure, a time-delay feature is added to this switch. A time-delay relay allows the compressor to run for a period of about 120 seconds after the low-pressure switch senses a low pressure. If the pressure does not return to its predetermined net value in that time interval, the compressor shuts off.

362.5 Troubleshooting Guide

Table 3-5, Troubleshooting Guide, lists the most common troubles that occur with reciprocal-type compressors and includes the probable causes of the listed troubles and recommended remedies for the correction of the troubles. Data in this guide is of a general nature and is intended to provide a standard approach to identifying and analyzing the most common troubles. It is recommended that this guide be reviewed at the local level and expanded, if necessary, to include the results of local experience.

NOTE

When performing troubleshooting procedures, observe all normal precautions for safeguarding both personnel and equipment.

363 CENTRIFUGAL COMPRESSORS

363.1 General

.11 **Description.** The centrifugal compressor consists of from two to six rotors or impellers mounted on a single shaft rotating in a housing. The rotating element is supported by bearings. Each rotor or impeller consists of two or more rows of axially-mounted vanes. Vapor, which will be compressed, flows from the center of the impeller to the outer edge. In the process, the rotating impeller imparts a high velocity to the vapor, increasing its kinetic energy. This energy is then converted to static pressure in the expanding section of the impeller housing. The result is the development of pressure necessary for the refrigeration cycle.

.12 **Impellers.** To achieve the pressure necessary in high-capacity refrigeration units, a single compressor may have from two to six impellers. Vapor from the discharge of one impeller is directed to the suction side of the next. Each impeller is designed to operate at the best efficiency for handling the vapor at each stage of compression.

TABLE 3-5

TROUBLESHOOTING GUIDE FOR RECIPROCAL-TYPE COMPRESSORS

COMPLAINT	CAUSE	POSSIBLE REMEDY
1. Compressor will not start.	a. Thermal overload elements in motor starter too small	a. Install correct elements.
	b. Bearings frozen	b. Replace bearings.
	c. No power	c. Investigate loss of power and make necessary repairs or corrections.
	d. Moving parts of compressor sticking	d. Disassemble compressor; clean or replace faulty parts.
2. Compressor stops.	a. Expansion valve stuck closed	a. Remove and free or replace valve.
	b. Leaky power element or expansion valve	b. Repair or replace power element.
	c. Shortage of condenser water	c. Increase supply of water.
	d. Air in condenser	d. Purge the air from the condenser and restart the compressor.
	e. Insufficient water or air over evaporator or condenser	e. Check reasons for insufficiency of water or air. Make necessary correction and restart compressor.
	f. Too much refrigerant in system	f. Remove excess refrigerant.
	g. Scale trap or suction side of compressor clogged	g. Remove obstruction and restart compressor.
3. Compressor starts and stops at frequent intervals (short-cycling).	a. Expansion valve obstructed	a. Remove and clean valve.
	b. Leaky power element on expansion valve	b. Repair or replace power element.
	c. Solenoid valve leaking	c. Replace valve.
	d. Strainer in liquid line clogged with dirt	d. Remove and clean strainer.
	e. Valve on liquid receiver partially closed	e. Replace valve.
	f. Obstruction in liquid line	f. Clear obstruction from line.
	g. Shortage of condenser water	g. Increase supply of water.
	h. Expansion valve improperly adjusted	h. Adjust to pass more liquid.
	i. Insufficient water or air over evaporative condenser	i. Check for insufficiency of water or air. Make necessary corrections and restart compressor.
	j. Low-pressure control set too high	j. Lower control setting.
	k. High-pressure control set too low	k. Increase control setting.
	l. Insufficient charge	l. Repair leak and add refrigerant.
4. Compressor is pounding.	Too much oil in crankcase	a. Drain excess oil.
5. Compressor is noisy.	Valve in compressor broken	a. Disassemble compressor and replace broken valves.
6. Suction connector and part of suction line is warm.	Suction valves leaking	a. Replace valves.

.13 Capacity. The centrifugal compressor is capable of handling large volumes of vapor. Because of their large capacity, centrifugal compressors are not ordinarily built in capacity ranges below 50 tons.

363.2 Compressor Type

.21 Open. The open-type compressor is so-called because one end of the impeller shaft extends beyond the compressor housing.

.22 Hermetic. The hermetic centrifugal compressor and its drive motor are completely enclosed within a sealed casing. The impellers and motor are mounted on the same shaft.

363.3 Controls

.31 Power Requirements. Maximum cooling requirements of a typical air-conditioning system last for only a few consecutive hours each day during the summer cooling season. During the remainder of the day, there may be long periods of constant partial load or a load varying from minimum to maximum in a relatively short time. Under these conditions, it is desirable to reduce or increase power requirements to meet cooling demand.

.32 Capacity Controls. Various methods of capacity control are used to obtain compressor efficiency at partial load. The most economical means is the use of adjustable inlet guide vanes. (See Figure 3-10.)

.33 Guide Vanes. The variable-inlet guide vane consists of a number of wedge-shaped center-pivoted dampers that divide the gas stream into several segments. A control device, through an actuator and linkages, positions all the guide vanes simultaneously. The reduction in area between the vanes, as they are moved automatically from the fully open position toward the closed position, causes a pressure drop that in turn increases the specific volume of the vapor entering the impeller and reduces the main flow. The guide vanes also impart a spin to the vapor flowing into the impeller in the direction of impeller rotation. The spinning vapor reduces the tendency for compressor stall at the inlet edge of the impeller blades, providing greater compressor stability and preventing surging.

.34 Other Control Methods. Other methods of accomplishing capacity control have been used and are currently available. They vary considerably in their effectiveness and efficiency at partial load. The methods listed below are inefficient in operation and are not common in postal facilities:

a. Off-and-on control

b. Condenser water regulation

c. Speed control

363.4 Safety Controls

.41 General. Certain controls have been incorporated into the centrifugal-compressor system to protect the motor from overload, to prevent the operation of the compressor unless the bearings have adequate lubrication, and to provide the proper sequence for starting the refrigeration system.

.42 Load-Limit Control. The load-limit control limits the current drawn by the motor to prevent motor burnout. Thermal-overload relays serve the same purpose when the demand of the refrigeration unit exceeds the capability of the drive motor.

.43 Oil-Pressure Control. The oil-pressure control measures the effective oil pressure at the bearings. This control prevents the compressor motor from starting until the oil pump is delivering oil at the proper rate and shuts the unit down if oil pressure drops below a preset limit.

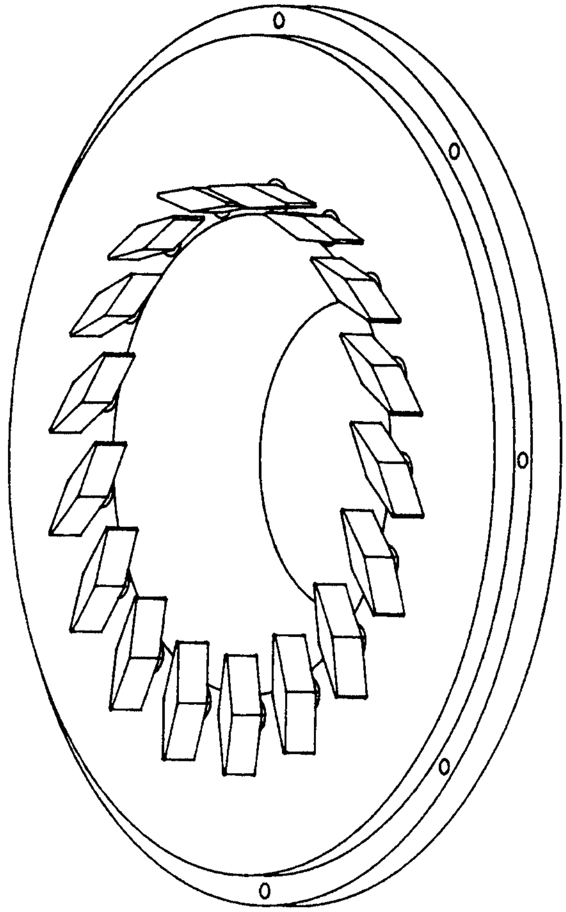


Figure 3-10

ADJUSTABLE INLET GUIDE VANE FOR CAPACITY CONTROL OF CENTRIFUGAL COMPRESSOR

.44 **Oil-Temperature Control.** The oil-temperature control and its components maintain the oil temperature at the point that prevents an excessive amount of refrigerant from being absorbed by the oil. This eliminates oil pump and compressor cutouts caused by oil foaming and loss of oil-pump prime.

.45 **Other Controls.** It is important that a proper sequence of events be scheduled for starting a centrifugal-refrigeration system. To prevent damage to the equipment, the system is provided with controls that will not allow the compressor to start until the chilled-water pump is circulating water through the evaporator. There are also lockout devices that ensure the condenser-water pump is circulating water through the condenser and cooling tower and that the cooling-tower fan motor is energized before the starting circuit to the compressor is closed. Through the safety controls, the compressor motor is stopped if any of the above auxiliaries fail. In this way, the system is protected against mechanical failure and improper operating procedure.

363.5 Troubleshooting Guide

Table 3-6, Troubleshooting Guide, lists the most common troubles that may occur to centrifugal-type compressors and includes the probable causes of the listed troubles and recommended remedies for the correction of the troubles. Data in this guide is of a general nature and is intended to provide a standard approach to identifying and analyzing the most common troubles. It is recommended that this guide be reviewed at the local level and expanded, if necessary, to include the results of local experience.

NOTE

While performing troubleshooting procedures, observe all normal precautions for safeguarding personnel and equipment.

370 CONDENSERS

371 GENERAL

371.1 Heat Transfer

The condenser transfers heat from the refrigeration system to a medium able to absorb and move it to a final disposal point. High-temperature, high-pressure refrigerant gas is discharged from the compressor to the condenser. The gas received at the condenser contains both sensible and latent heat. Upon entering the condenser, the heat is gradually transferred from the gas to the cooling medium, either air or water or, in some cases, both.

371.2 Temperature-Btu Chart

Figure 3-11 shows what happens to the refrigerant in a condenser. This chart is known as a Temperature-Btu Chart, as the vertical scale is in degrees

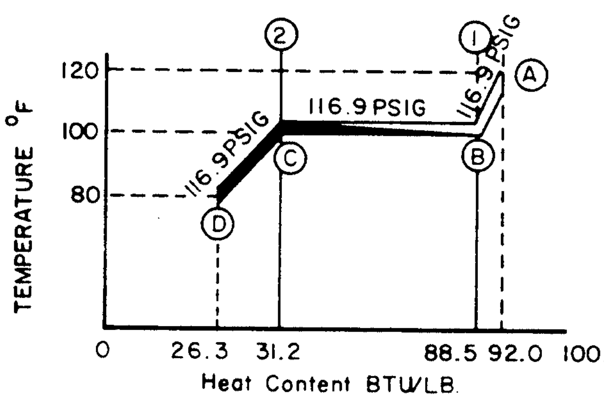


Figure 3-11
TEMPERATURE-BTU CHART

TABLE 3-6

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE COMPRESSORS

COMPLAINT	CAUSE	POSSIBLE REMEDY
1. Compressor will not start.	a. Power failure	a. Check for building power failure. Check and reset circuit breaker.
	b. Disconnect or control switch open	b. Determine why switch was opened. If everything normal, close switch.
	c. Overload relays in starter tripped	c. Check overload relays and reset.
	d. Vanes are open and/or vane closed switch is open	d. Check position of vane motor and vane closed switch. Vane closed switch must be closed for starting.
	e. Oil pump not running	e. Check for faulty oil pump starter, circuit breaker, fuses, or starting switch. Check for faulty wiring from the pump starter to the pump. Check for faulty pump motor.
	f. Low oil pressure, or defective cutout switch	f. Check to be sure that the low oil pressure cutout contacts are closed. Check low oil pressure cutout switch for improper setting. Check oil level; add oil if required.
	g. Water pumps not running	g. Check cooler and condenser water pump for operation. If a pilot relay is installed for automatic pump starting, check relay for possible sticking contacts.
	h. Refrigerant temperature below normal	h. Check low refrigerant cutout switch for proper setting. Check refrigerant level. Determine cause of refrigerant loss. Add refrigerant. Check leaving chilled-water temperature to be sure it is not below normal. Check cooler float valve. Be sure it is not binding. Binding float would cause refrigerant to accumulate in condenser.
	i. High condenser pressure	i. Check items listed under Item 7.
	j. Chilled-water temperature below normal	j. Check the chilled-water temperature. If below normal, allow the temperature to rise and machine will restart automatically. Chilled-water pump should be running.
	k. Improper setting of chilled-water low temperature cutout and recycle switch.	k. Check setting. Reset if necessary.

TABLE 3-6 (Continued)

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE COMPRESSORS

COMPLAINT	CAUSE	POSSIBLE REMEDY
2. Chilled-water temperature is too high (compressor is running).	a. Chilled-water thermostat set too high	a. Check and reset poisition of thermostat.
	b. High temperature in conditioned area	b. Machine loaded to capacity. Excessive infiltration of outside air may be the cause.
	c. Vanes not fully open	c. Excessive load in conditioned area. Vane opening limited by the motor overload module. Check vane motor and vane linkage to be sure that linkage and shaft are not slipping.
	d. High condenser pressure	d. Check Item 7 for causes of high condenser pressure.
	e. Gradual increase in temperature difference in refrigerant and chilled water	e. Shut down the machine and check refrigerant loss. Add refrigerant as required. Check cooler for dirty or obstructed tubes and clean if necessary. Check the division plates and division plate gaskets in cooler water box for possible water bypass.
	f. Shortage of refrigerant	f. Determine cause of loss. Repair, as required. Add refrigerant.
3. Chilled water temperature is too low (compressor is running).	a. Chilled water thermostat set too low	a. Reset thermostat.
	b. Vanes open too far	b. Check to be sure "thermostatic-manual" switch is in the "thermostatic" position. Check calibration of chilled-water module.
	c. Low chilled-water temperature cutout and recycle switch not operating properly	c. Check setting of recycle control. Reset if necessary. Control must shut down the machine when the water temperature is 5 °F below design temperature.
4. Compressor short-cycles.	a. Chilled-water temperature control not functioning properly	a. Repair or replace control.
	b. Air compressor not supplying proper air pressure to pneumatic control circuit	b. Repair compressor and air lines, as required.
	c. Pneumatic-electric switch not functioning properly	c. Check switch and determine cause of trouble. Repair or replace.
	d. Dirty oil filter malfunctioning regulating valve	d. Clean filter or repair regulating valve.
5. Suction pressure is too high.	Excessive load on evaporator	Look for excessive infiltration of warm air into conditioned space and correct.
6. Suction pressure is too low.	a. Lack of refrigerant	a. Correct cause of refrigerant loss. Add refrigerant.
	b. Vane control switch on "manual"	b. Place switch on automatic.
	c. Water in chilled-water circuit being bypassed around evaporator or insufficient flow of water through evaporator	c. Adjust chilled-water circuit valves.
	d. Chilled-water temperature control set too low or not functioning properly	d. Check action of temperature control. Repair or replace.
	e. Chilled-water thermostat not set correctly	e. Reset thermostat.

TABLE 3-6 (Continued)

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE COMPRESSORS

COMPLAINT	CAUSE	POSSIBLE REMEDY
7. Condenser pressure is too high.	a. Low condenser water flow, or high condensing water temperature	a. Check condensing water pump for proper operation. Check to be sure all valves in condensing water circuit are open. Check cooling tower fan and fan control for proper operation. Check tower makeup water valve to be sure valve is not stuck closed. Check strainer in condenser water line. Check condensing water temperature in and out of condenser to determine if water box division plate or gaskets are damaged. This could cause water bypass.
	b. Air in condenser	b. Check for presence of air and purge if necessary. Check purge for proper valve and switch settings.
	c. Fouled condenser tubes	c. Check for fouled condenser tubes and clean if necessary.
8. Condenser pressure is too low.	Excessive water flow or water temperature too low	Check for excessive flow. Adjust flow to maintain minimum leaving condenser water temperature.
9. Compressor cuts out.	a. Low voltage	a. Contact power company. Regulate voltage.
	b. Starter overloads incorrectly set	b. Correct setting of overloads.
	c. Load limit relay not properly set	c. Correct setting of load limit relay.
	d. Lack of refrigerant	d. Correct cause of refrigerant loss. Add refrigerant.
	e. Light load on evaporator	e. Adjust chilled-water circuit valves.
	f. Chilled-water temperature control set too low or not functioning properly	f. Check action of temperature control. Repair or replace.
	g. Pilot positioner and vane operator not set correctly	g. Reset pilot positioner and vane operator.
	h. Low temperature control not functioning properly	h. Readjust, repair, or replace low temperature control.
	i. High pressure control not functioning properly	i. Readjust, repair or replace high pressure control.
	j. Insufficient oil charge	j. Locate and correct cause of oil loss. Add oil.
10. Oil temperature in sump is too low.	a. Oil temperature control not functioning correctly	a. Check action of temperature control. Adjust, repair, or replace.
	b. Water valve stuck open	b. Clean water valve.
	c. Oil heater burned out	c. Replace heater.
	d. Refrigerant in oil	d. Check and reset or repair heater.
11. Oil temperature in sump is too high.	a. Oil temperature control not functioning correctly	a. Check action of temperature control. Adjust, repair, or replace.
	b. Water valve not opening	b. Replace coil. Clean water valve.
	c. Manual valve in water line closed	c. Open valve.
	d. Cooling coil fouled	d. Clean cooling coil.
12. Compressor surges.	High condensing pressure	See Item 7.

TABLE 3-6 (Continued)

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE COMPRESSORS

COMPLAINT	CAUSE	POSSIBLE REMEDY
13. Purge unit will not build up pressure.	a. Purge condenser float valve stuck in open position	a. Remove purge condenser head and clean or repair float valve mechanism.
	b. Purge compressor valve worn	b. Repair or replace valve plate assembly.
	c. Valves between condenser and purge compressor closed	c. Open valves.
	d. Regulating valve to purge unit not opening	d. Repair or replace valve.
14. Purge unit relieves at too low a pressure.	Relief valve stuck or set too low	Repair, clean, adjust, or replace relief valve.
15. Purge unit relieves liquid from condenser relief valve.	a. Float valve stuck shut or float assembly rotated out of proper position in purge drum head	a. Remove purge condenser head and clean or repair float valve mechanism.
	b. Manual valve on purge return line at evaporator closed	b. Open valve.
16. Purge compressor loses oil.	a. Oil separator heater not functioning	a. Replace burned-out heater. Check setting and action of purge temperature control. Readjust, repair or replace.
	b. Oil separator float valve stuck shut	b. Remove purge unit oil separator. Clean or repair float assembly.
17. Mixture in purge condenser is dark in color and sight glass is etched.	Oil separator heater set too high	Reset purge temperature control. Replace oil in purge unit. Clean compressor, oil separator, and purge condenser. Check for damaged compressor.
18. Purge does not operate in "auto" position.	a. Normal	a. Purge pump cycling may not be required if machine tightness does not warrant. Compare purge and condenser pressure gauges to determine if purge should be cycling. If purge should be cycling, check the condenser for evidence of air present.
	b. Blown fuse	b. Check fuse. Replace if necessary.
	c. Loose connections or broken wires	c. Check electrical connections at purge switch, solenoid switch, and coil; purge motor and fuse. Be sure connections are tight and wires or their insulation are not broken.
	d. Defective purge electrical switch	d. Disconnect the leads from the purge switch and check it with a voltohmmeter using the ohm scale with the leads across the switch lugs. Check the switch for continuity with the switch in the closed position. Replace switch if faulty. The solenoid switch can be checked in a similar manner.
	e. Incorrect purge safety or operating switch setting	e. Recalibrate the purge operating switch or the purge switch settings.

TABLE 3-6 (Continued)

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE COMPRESSORS

COMPLAINT	CAUSE	POSSIBLE REMEDY
19. Purge cycles are often in "auto" position.	a. Purge valves not tightly closed	a. Check to be sure that the purge valves are set in accordance with the purge valve chart. Be sure that the valves that should be closed are closed tightly.
	b. Solenoid valve or check valve leaking	b. The direct acting solenoid valve and check valve prevent leakage from atmosphere to the condensing chamber. If found leaking, replace the valves. The replacement valves must be designed for refrigerant duty.
	c. Incorrect operating switch setting	c. Recalibrate the purge operating switch to the proper setting.
	d. Excessive air leakage into machine	d. Check machine for leak tightness with halide leak detector.
	e. Float valve stuck in closed position	e. Check float chamber to be sure that a refrigerant level can be seen. If level is above the sight glass, valve is stuck in closed position. Remove the valve and determine cause of sticking.
20. There is excessive refrigerant loss.	a. Purge pump cycles often in "auto" position	a. See Item 19 for causes.
	b. Float valve stuck in closed position or refrigerant return line plugged	b. Check float valve chambers for refrigerant level. If level is above the sight glass, valve is stuck in closed position. Check refrigerant return line for obstructions. Correct as required.

Fahrenheit and the horizontal scale is in Btu heat content of the refrigerant. For this illustration, Refrigerant 12 at 116.9 psig is used. The corresponding condensing temperature is 100 ^{o}F. The same pressure 116.9 psig is present throughout the condensing and cooling cycle in the condenser.

371.3 Cooling

Hot refrigerant gas from the compressor enters the condenser at 120 ^{o}F (point A). The gas at this point has 20 ^{o}F superheat. As this gas comes into contact with the cooler surfaces of the condenser, it begins to give up its heat and is gradually cooled to 100 ^{o}F, the saturation temperature corresponding to its pressure. The temperature drop from 120 ^{o}F to 100 ^{o}F is represented by the line from A to B. All heat removed from A to B is sensible heat. Heat removal continues until all the gas condenses to a liquid (point C). Note that the temperature has not changed from B to C. All heat removed in this area is latent heat; therefore, there is no temperature change. Since all the refrigerant is now a liquid, further cooling will subcool it below the condensing temperature of 100 ^{o}F. In normally operated condensers, there would be some degree of subcooling. In this example, the liquid is subcooled 20 ^{o}F to point D and leaves the condenser at 80 ^{o}F.

371.4 Sensible/Latent Heat

An interesting point shown in this chart is the small amount of sensible heat removed compared to the latent heat removed. The sensible heat removal from A to B is only 3.5 Btus/lb of refrigerant. From C to D only 4.9 Btus have been removed. This is a total of 8.4 Btus of sensible heat removed compared to 57.3 Btus of latent heat removed between points B and C. This emphasizes the point that most of the heat removed in a condenser is latent heat. A basic concept of condenser theory is that the heat given up by the refrigerant must equal the heat gained by the cooling medium.

372 AIR-COOLED CONDENSERS

372.1 Types

There are two types of air-cooled condensers; natural-draft and forced-air.

.11 **Natural-Draft Condensers.** The natural-draft, air-cooled condenser is normally found in one of two types of construction: The tube and fin, or the plate-type, in which the plates are pressed into the outline of the condenser coil and welded together. This leaves interior space for tubes through which the hot refrigerant gas passes. Because the air moves very slowly across the surface of the natural-draft condenser, relatively large surfaces are required for heat transfer, resulting in very limited usage.

.12 **Forced-Air Condensers.** The forced-air condenser is usually of the tube and fin construction and uses either a propeller or a centrifugal fan, depending upon such design factors as air resistance, noise level, or space requirements. The increased airflow makes this type condenser more practical for larger installations. Figure 3-12 shows a typical forced-air condenser. In addition, vertical airflow is recommended to avoid airflow interference by walls and other obstructions and to avoid wind resistance problems.

372.2 Maintenance

Air-cooled condensers rely on the air circulating through the condenser to effect the proper heat transfer. For this reason, the principal maintenance function is to keep airflow through the condenser unobstructed and to maintain sufficient distance between the discharge side of the condenser, the

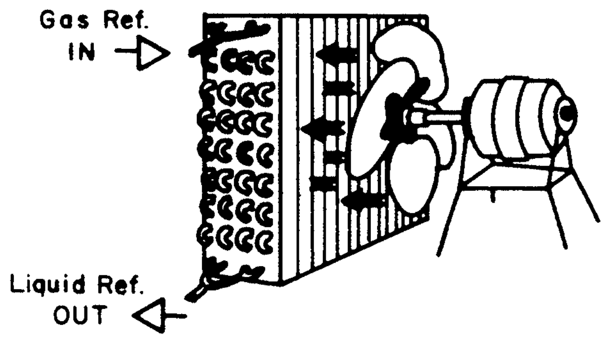


Figure 3-12
FORCED-AIR CONDENSER

walls, and other objects, so that the airflow is not restricted.

373 WATER-COOLED CONDENSERS

373.1 Types

Water-cooled condensers use water as the condensing medium. The two basic types used in post office installations are the shell and tube, and the shell and coil.

373.2 Shell and Tube

.21 **Design.** Shell and tube condensers consist of a large number of 3/4 or 5/8 tubes installed inside a steel shell. The water flows inside the tubes while the refrigerant vapor flows outside, around the nest of tubes. The vapor condenses on the outside surface of the tubes and drips to the bottom of the condenser shell used as a receiver for the storage of liquid refrigerant. Shell and tube condensers are used for practically all water-cooled refrigeration systems.

.22 **Heat Transfer.** In order to obtain a high rate of heat transfer through the surface of a condenser, water must pass through the tubes at a fairly high velocity. For this reason, the tubes in shell and tube condensers are separated into several groups while the same water travels in series through each group. A condenser with four groups of tubes is known as a four-pass condenser, because the water flows back and forth along the length of the condenser four times. Four-pass condensers are common, although any reasonable number of passes may be used. The fewer number of passes in a condenser, the greater the number of tubes in each pass.

.23 **Operation.** Figure 3-13 shows a typical water-cooled condenser. Hot gas from the compressor is admitted (point A) and flows downward over the tubes (point B). Cold water from the cooling tower is circulated through the tubes and, being cooler, absorbs heat from the hot gas. The heat surrendered by the gas

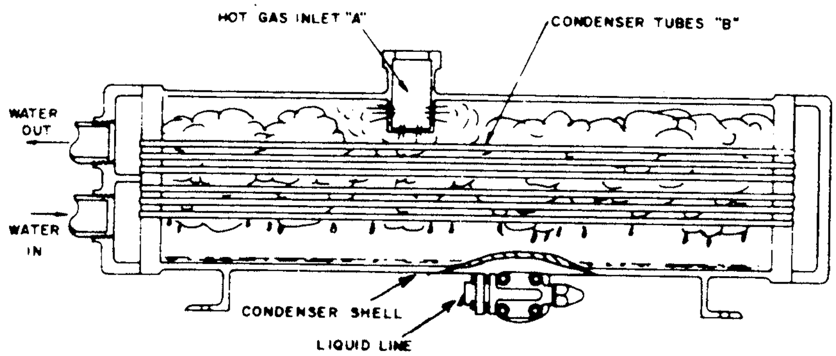


Figure 3-13
OPERATION OF WATER-COOLED CONDENSER

raises the temperature of the water. The gas, upon surrendering a sufficient amount of heat, condenses on the cold surfaces of the tubes and runs to the bottom of the condenser shell where it collects until it is used.

373.3 Shell and Coil

A shell and coil condenser is simply a continuous copper coil mounted inside a steel shell. Water flows through the coil, and refrigerant vapor from the compressor is discharged inside the shell to condense on the outside of the cold tubes. In many designs, the shell also serves as a liquid receiver. The shell and coil condenser has a low manufacturing cost, but this is offset by its maintenance cost. If a leak develops in the coil, the head must be removed from the shell and the entire coil removed in order to find and repair the leak. A continuous coil is a nuisance to clean, whereas straight tubes are easy to clean with mechanical tube cleaners. The shell and coil condenser is seldom found in postal installations.

374 EVAPORATIVE CONDENSERS

374.1 Operation

In an evaporative condenser, the refrigerant vapor is condensed as it passes through pipes over which water is sprayed. The cooling water flows downward in an open flow over the outside of a vertical coil of pipe containing the refrigerant. Some of the water is evaporated and is carried off by the air stream flowing from bottom to top and is discharged outdoors through duct work. Evaporative condensers are sometimes confused with cooling towers since they use a fan and water operating within a housing similar to a cooling tower. Figure 3-14 shows two typical evaporative condensers.

374.2 Location

An evaporative condenser may be located outdoors or in an indoor equipment room. The outdoor location is recommended only when operation is limited to temperatures above freezing, as it is impractical to run an evaporative condenser without spray water.

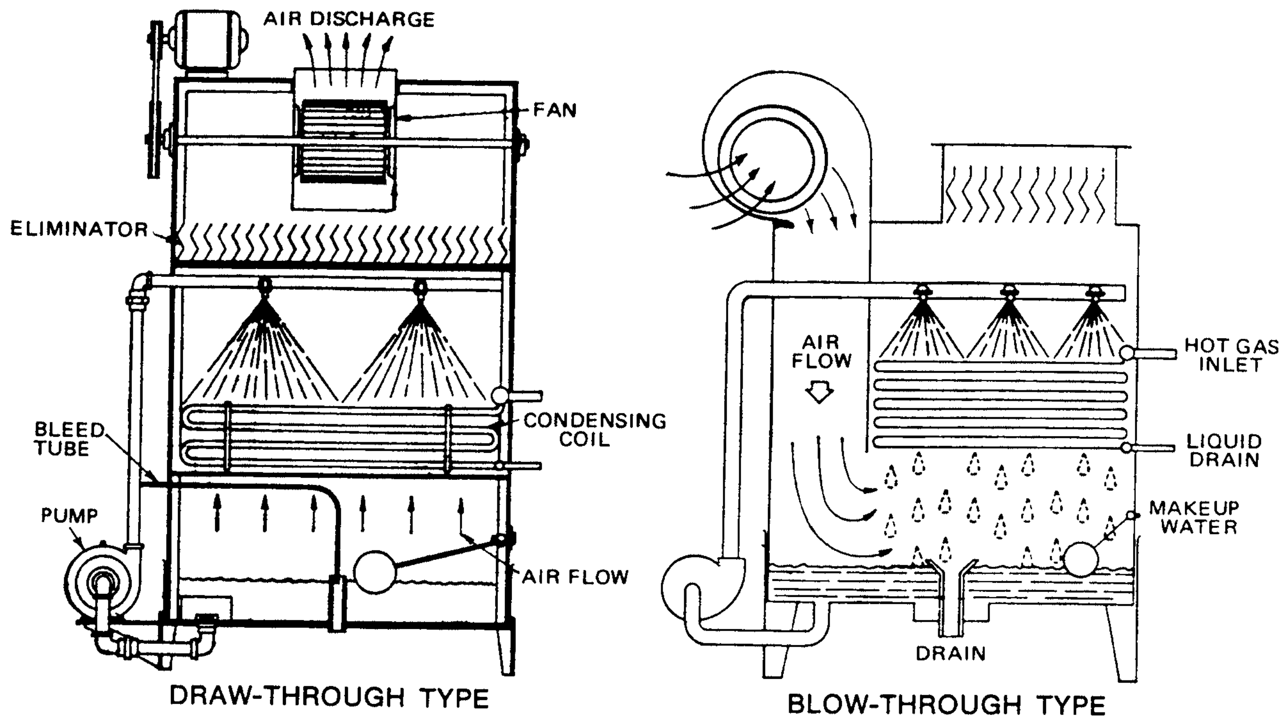


Figure 3-14
EVAPORATIVE CONDENSERS

375 CONDENSER

The capacity of a water-cooled condenser is affected by the temperature of the water, the quantity of water circulated, and the temperature of the refrigerant gas. The amount of condenser water required for any specific condensing unit must be determined from the manufacturer's data. While well-designed condensers of different makes will probably have approximately the same capacity for a given water rate, this is not true for all makes. Since comfortable air-conditioning requires 240 Btus/min per ton heat transfer to the condenser water with a temperature rise of 10 ^{o}F , a good rule of thumb is 3 gallons per minute of condenser water will be required for each ton of refrigeration.

376 CONDENSER FOULING

The main function of a water-cooled condenser is to transfer heat from the hot refrigerant gas to the cool condenser water. This heat transfer must take place through the walls of the condenser tubes. Due to the high temperatures present in condensers, impurities in the condenser water will gradually buildup on the water side of the condenser tubes, decreasing the overall heat transfer rate. Water with a high degree of hardness or impurities forms scale on the inside of the tubes if not properly treated, or if cycles of concentration are not properly controlled by bleed off.

377 CONDENSER CLEANING

Condensers that become fouled, either by sludge or scale, require cleaning to restore proper heat transfer. There are two standard cleaning methods:

a. The acid cleaning method is used primarily to remove scale deposits rather than slime or sludge. (See Chapter 4 for a detailed discussion of acid cleaning.)

b. The mechanical method is recommended for removing slime and sludge that has settled in the tubing. One or both ends of the condenser must be removed to gain access to the tubes. A nylon brush, sized to the tubes being cleaned and attached to a long rod, makes an effective tool to free foreign matter in the tubes. After the tubes have been brushed clean, flush by running cool water through them. Replace gaskets, if necessary, when reassembling the condenser end plates. Cross-tighten nuts on end plate bolts.

380 EVAPORATORS AND CHILLERS

381 GENERAL OPERATION

The evaporator is the part of the refrigeration system in which the refrigerant removes the unwanted heat. Liquid refrigerant is released through an expansion valve into a reduced pressure area called the evaporator. As the liquid comes in contact with the evaporator tubes, it is cooler than the surrounding area to be cooled. Heat then flows from the surrounding area into the evaporating liquid. As the liquid continues to flow through the tubes, more and more of it evaporates, until it all has evaporated and leaves the evaporator as a gas. In theory, the heat picked up by the refrigerant must equal the heat given up by the medium being cooled. If the area to be cooled is located some distance from the evaporator, the evaporator cools water that is piped to the area and circulated through cooling coils. In this use, the evaporator is also known as a chiller.

382 TYPES

382.1 General

There are two basic types of evaporators: The dry or direct-expansion type, and the flooded-coil type.

382.2 Direct Expansion

The direct-expansion evaporator is usually placed in the space to be cooled. The air to be cooled flows over a bank of tubes and gives up its heat to the refrigerant inside the tubes. The refrigerant is metered to the tubes through an expansion valve.

382.3 Flooded Coil

In the flooded-coil evaporator, the cooling coils carry the water to be chilled and are almost entirely covered with liquid refrigerant. In one type, referred to as a low-side float, the float valve maintains the liquid refrigerant at a constant level. As fast as the liquid refrigerant evaporates, more liquid is admitted by the float. As a result, the entire interior of the evaporator is always filled with liquid up to the float level.

383 TEMPERATURE

The temperature of the water leaving the chiller can be controlled by adjusting the flow rate of water within a given range depending on the size of the chiller.

384 METERING DEVICES

384.1 General

Metering devices regulate the amount of liquid refrigerant passing into the evaporator. They deliver about the same amount of liquid refrigerant which, after vaporization, is removed by the compressor, regardless of the load. In general, there are three types of metering devices used on direct-expansion evaporators; the constant-pressure expansion valve, the thermal-expansion valve, and the capillary tube. The flooded-coil evaporator generally uses the high-pressure and low-pressure float valve.

384.2 Constant-Pressure Expansion Valve

The constant-pressure expansion valve maintains a constant pressure in the evaporator regardless of the cooling load.

384.3 Thermal-Expansion Valve

.31 **Operation.** The thermal-expansion valve is controlled by a combination of the temperature and pressure of the refrigerant vapor leaving the evaporator.

.32 **Design.** In construction, the thermal-expansion valve is similar to the constant-pressure valve, except that a thermal bulb and additional bellows have been added. Instead of the spring acting against the suction pressure, it acts with the suction or evaporator pressure. Both the suction and spring pressures tend to move the valve stem to the closed position. The pressure exerted by the refrigerant fluid in the thermal bulb counteracts the tendency of the spring and evaporator pressure to close the valve. The bulb is either attached to the suction pipe or inserted into it and connected by a tube to the counteracting bellows. The liquid inside the bulb, as a result, is always approximately the same temperature as the superheated vapor leaving the evaporator. Enough liquid is always vaporized inside the bulb to maintain a pressure in the connecting tube and counteracting bellows.

.33 **Pressure Control.** Because the temperature of the liquid inside the bulb is very close to the temperature of the superheated refrigerant vapor leaving the evaporator, the pressure exerted by the vapor in the counteracting bellows is greater than the pressure inside the evaporator and inside the bellows that sense the evaporator pressure. Thus, if a refrigerant boils at a given temperature in the evaporator and is superheated to a higher temperature before it leaves the evaporator, the pressure in the counteracting bellows will be higher than the bellows that sense the evaporator pressure. Except for the action of the spring, this difference in pressure would be enough to open the valve and keep it wide open. By the proper setting of an adjusting screw, the spring compensates for the difference in pressure and maintains the valve in a balanced position at all times. Because the thermal-expansion valve is adjustable to maintain a predetermined degree of vapor superheat, it automatically adjusts the amount of liquid refrigerant admitted to the evaporator. As each evaporator has its own thermal-expansion valve, any number of evaporators can be operated, in parallel, on one compressor up to the capacity of the compressor.

384.4 Capillary Tube

A third type of direct-expansion metering device is the capillary tube in the liquid line that conducts the liquid refrigerant to the evaporator. To get the desired drop in pressure, the tube is made with a small inside diameter. The pressure drop is varied by cutting the narrow tube to the appropriate length. This metering device is generally used on small equipment with comparatively constant loads (such as room air-conditioners).

384.5 Float Valve

The float valve is generally used with flooded-coil or flooded-shell/and/tube evaporators. The float ball may be located directly in the evaporator, in a chamber next to the evaporator, on the low- or high-pressure side of the evaporator. With the valve located on the low-pressure side, both top and bottom sections of the float chamber are connected to the evaporator. With this arrangement, the liquid level in the chamber is the same as that in the evaporator. When the liquid level in the evaporator drops due to an increase in load, the level in the chamber also drops. As the float drops, the valve opens, admitting liquid to the evaporator until the float again closes the valve. When the float valve is located on the high-pressure side, the float is immersed in high-pressure liquid. As fast as the vaporized refrigerant condenses, it flows to the float chamber. As the liquid level in the chamber rises, the float opens the valve and allows the liquid to flow into the evaporator. This metering device allows liquid to flow to the evaporator at the same rate that it is condensed. Because of this, there is no provision for storing liquid other than in the evaporator.

390 COOLING TOWERS

391 GENERAL

In cooling towers, the water from the tower is circulated through the refrigerant condenser and then returned to the tower. It passes through the tower, and is recirculated through the refrigerant condenser again (Figure 3-15). The cooling tower conserves water and lowers the temperature of the water being circulated. Where the cost of water is not prohibitive, condensing-water systems are sometimes designed as a "once-through" system in which the cooling tower is eliminated and the condensing water is wasted directly to a sewer connection. Normally, cooling towers are provided to avoid waste. A cooling-tower system may be classed as an "open system" since it is open to atmosphere at the tower.

392 DESCRIPTION

Mechanical-draft cooling towers use fan power to move air rather than natural draft or wind velocity. This gives the tower designer control over the air supply. Correct amounts of air at the required velocity can be readily selected to meet cooling requirements. Mechanical-draft towers are classified as forced-or induced-draft. Mechanical-draft towers require less space and less piping than atmospheric towers. Lower water temperatures resulting from this design usually boost overall plant economy enough to cover the added operating expense and higher initial cost of the installation.

393 OPERATION

393.1 General

.11 Design. The cooling-tower shell is vertical and made of wood, metal, transite, plastic, or other materials. Flumes or spray nozzles distribute water near the top of the shell. As the water splashes down over the packing, it breaks into small drops, flooding a maximum surface. This falling water passes through a flow of air circulated upward through the tower by forced-or induced-draft fans, and drops into a collecting basin at the bottom.

.12 Controls. Special baffles called drift eliminators are placed above the inlet-water distribution system to prevent excessive loss of entrained moisture and the operating nuisance that it creates. When cooling water through a 10-degree range, loss of

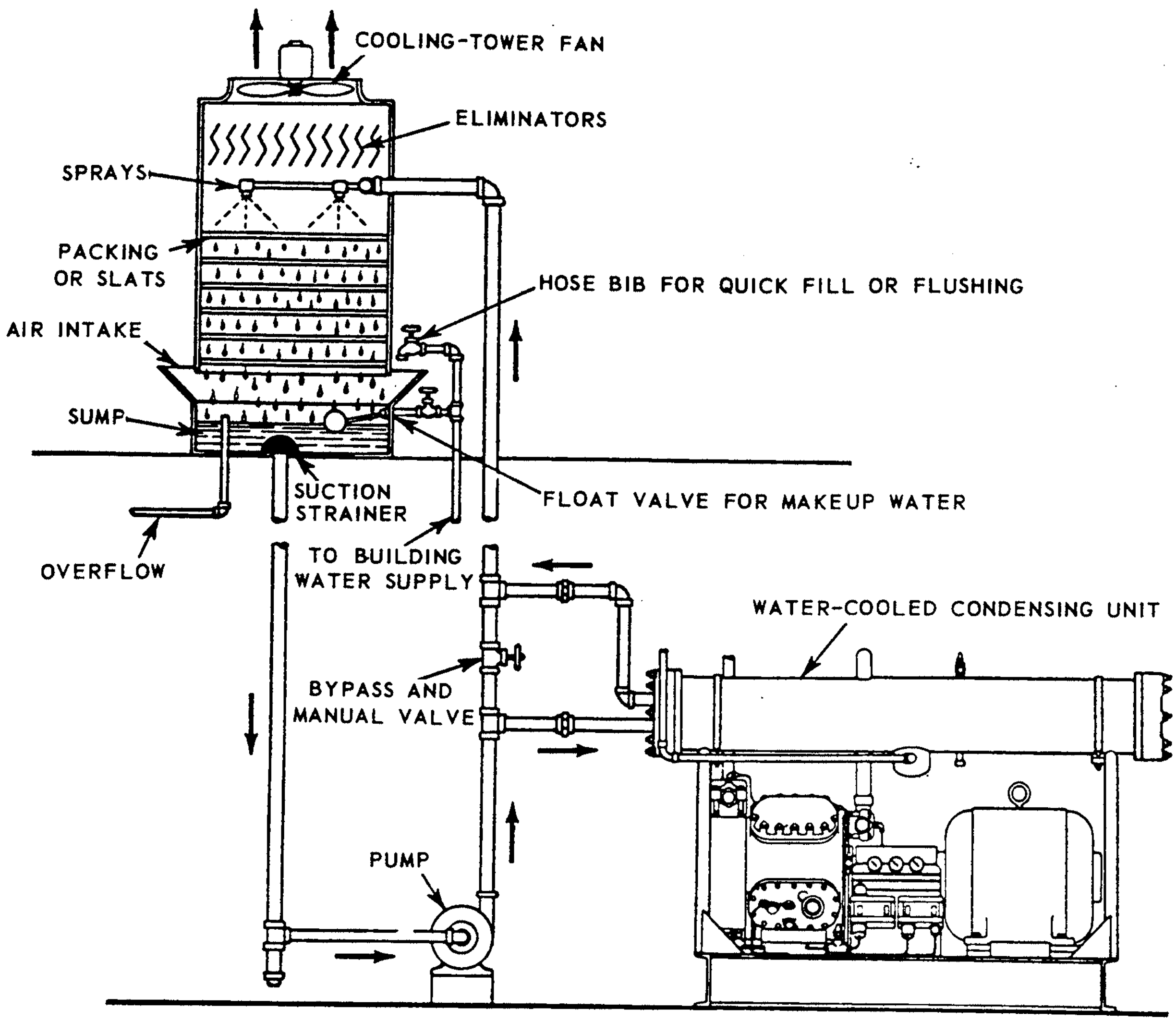


Figure 3-15

TYPICAL COOLING-TOWER SYSTEM

water by evaporation and drift totals about one percent of design circulation. Air velocity is in the range of 300 to 700 fpm; water-pumping head varies from 11 to 50 feet.

.13 **Capacity.** Cooling capacity is improved by increasing the amount of filling, or by increasing the height of the tower. These improvements stretch the contact time of water and air without additional fan power. Heat transfer can also be increased by moving more air through the tower. Reduced contact time of air and water is then more than offset by increased temperature difference between water temperature and wet-bulb temperature of the air.

393.2 Forced-Draft Tower

In forced-draft towers, the fans are located at the air intake (Figure 3-16). On a solid foundation, vibration and noise are minimized because mechanical equipment is set near the tower's base. Since the fan handles mostly dry air, fan-blade corrosion and moisture condensation in the gear box are avoided. These designs are slightly more efficient than induced-draft types; however, hot, humid exhaust vapors from the top of the tower tend to recirculate back to the low-pressure air-intake region. If winds are unfavorable, recirculation can reduce efficiency by as much as 20 percent. In cold weather, recirculation often causes ice to form on nearby equipment, buildings, or in the fan housing itself. Frost in the fan outlet of forced-draft towers has been known to actually break the fan blades. Tower design limits fan size to 12 feet in diameter or less. Large-capacity units then require multiple fans, motors, and starters in parallel.

393.3 Induced-Draft Tower

.31 **Design.** There are two types of design for induced-draft towers; counterflow and crossflow. Counterflow units have a fan on top that draws air up against the water falling through the filling (see Figure 3-17). The main advantages are that the coldest water contacts the driest air and the warmest water contacts the most humid air. Recirculation is seldom a problem since the outlet fan discharges hot air upward, directly away from the air-intake louver below. Larger fans, up to 60 feet in diameter, can be used with this design.

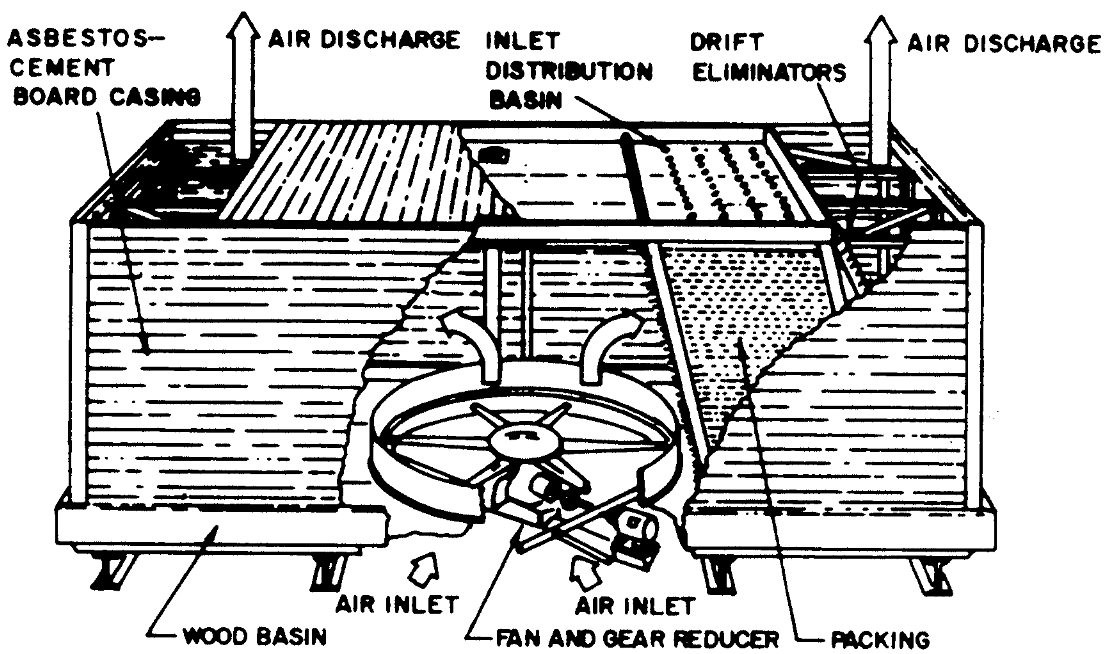


Figure 3-16

FORCED-DRAFT TOWER

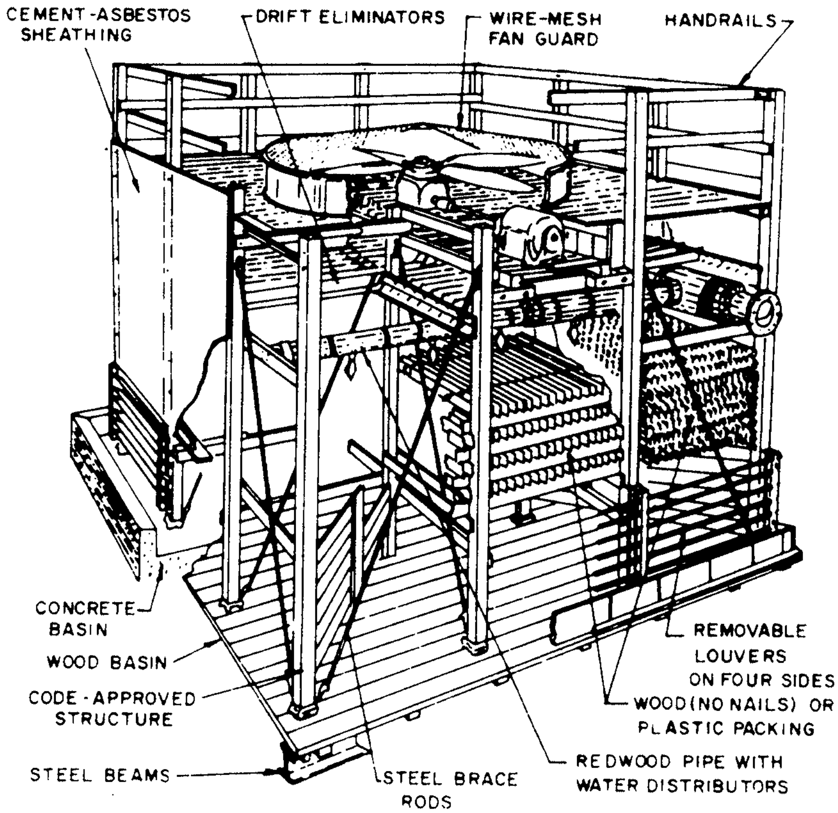


Figure 3-17

INDUCED-DRAFT TOWER

.32 **Airflow.** The restricted area at the base of induced-draft towers tends to choke off flow of high-velocity inlet air. The path air must follow upward against falling water generates higher static-pressure loss, and increases fan horsepower requirements compared to a crossflow tower handling equivalent air-water flow. However, this is offset by using efficient film-type packing. Counterflow design then handles the same cooling load as crossflow design, with less air column.

.33 **Air Velocities.** Air velocities through the filling are usually unevenly distributed, with very little movement near the walls and center of the tower. This problem is readily eliminated by the filling design and the proper orientation of counterflow tower internal structure.

393.4 Crossflow Induced-Draft Tower

Crossflow induced-draft towers provide horizontal airflow as water falls across the filling. The fan is centered at the tip of the unit and draws air through two cells paired to a suction chamber partitioned midway beneath the fan. Drift eliminators are fitted to turn the air upward toward the outlet fan. Water falls from the distribution pan in a cascade of small drops over the filling and across the horizontal flow of air. Since there is less resistance to airflow, draft loss is lower. Offsetting this gain is the fact that more air is required compared to counterflow draft designs.

393.5 Factors Influencing Operation Of Cooling Towers

.51 **Evaporation.** When the condensing water passes over the cooling tower, a portion is lost to evaporation. The loss amounts to about one percent of the water quantity circulated per 10 °F drop in water temperature through the tower. The evaporation produces the cooling effect needed to lower the temperature of the water being circulated back to the condenser. As evaporation takes place, the dissolved solids in the evaporated water are left behind, resulting in an increase in the amount of solids in the circulated water. Depending on conditions, the solids in the condensing water may become concentrated to a point where they are precipitated out of the water solution as sludge or scale. Due to the physical or chemical characteristics of the solids, the precipitation is usually greatest in the hottest part of the system, the condenser area. (For instance, the ability of calcium carbonate to remain in solution decreases as the temperature increases.)

.52 **Air Exposure.** Most cooling towers used at postal facilities are the mechanical-draft type where a fan forces air through the tower and over its wetted portions. Along with the desired effect of lowering the temperature of the water, the tower has an unfavorable side effect: It washes out of the air any smoke, dust, dirt, bacteria, gases, etc., that are present. The dust and dirt show up as mud or silt in the cooling-tower sump. The bacteria and other organisms promote the growth of slime and algae. Acid gases (such as sulfur dioxide from a nearby chimney) may change a neutral water to a very corrosive one. Mud, silt, etc., may be washed into the circulating-water system and accumulate on the condenser as sludge.

.53 **Bleed Off.** The concentration of solids may be held in check by bleeding off some of the concentrated circulating water and replacing it with more diluted makeup water. Therefore, it is standard practice to provide a bleed line at the tower that wastes a portion of the water from the system to avoid excessive buildup of dissolved solids. Considering the purpose and importance of bleed off, every tower must be equipped with a bleed line and an adequate rate of bleed must be established. The required amount of bleed is determined by evaluating the chemical characteristics of the water, the type of water treatment, if any, to be employed and other factors. (This is fully covered in Chapter 4.) The bleed line at the tower should be tapped into the circulating system just ahead of the inlet discharge, so that when the circulating pump is in operation water is bled to waste only. The bleed-line discharge should be piped to the nearest sanitary sewer.

.54 **Water Losses and Makeup.** When a cooling tower is operating, the float valve in the basin or sump of the tower admits water to the system to make up for the water lost as a result of evaporation, windage, splash, and deliberate bleed. Neglecting splash and leakage, the amount of makeup represents the sum of evaporation, windage, and bleed. Evaporation represents a loss of approximately one percent of the circulating water. (See Section 393.12.) In a mechanical-draft tower, windage represents a 0.1 to 0.3 percent loss. Evaporation and windage are characteristics of system design. Bleed is adjusted as required.

.55 **Cycles of Concentration.** The cycles of concentration are one way of comparing the dissolved solids in the circulating water with those in the makeup or raw water. If, as a result of evaporation, the solids in the tower water become twice as great as those in the makeup, there are said to be two cycles of concentration. Three times as many solids would result in three cycles of concentration, four times would be four cycles, and so on. The maximum allowable cycles of concentration are predetermined by analysis of the makeup water and other factors. During temporary water shortages, treatment can be increased beyond the normal cycles to allow operation with increased cycles of concentration and reduced bleed off. Only under extreme conditions should the bleed off be reduced below the safe level to prevent scale formation with maximum chemical treatment. When this is necessary, the following actions must be taken:

a. Reduce air-conditioning load as much as possible.

b. If possible, operate only one chiller (where two or more are available) to prevent scaling the tubes in both units during severe temporary conditions.

c. Carefully maintain and monitor the chiller operating log to determine the severity of scale formation.

d. After the temporary shortage is over, clean the condenser to remove scale. This usually requires mechanical removal of deposits, however, depending on the severity and type of scale, it may be done by chemical treatment.

NOTE

See Chapter 4 for further information on controlling cycles of concentration.

394 CAPACITIES

Knowing how much water is used in the system, and the actual heat the water picks up for each ton of refrigeration actually produced, is necessary to calculate the capacity of a cooling tower. It is standard practice to size motor-driven cooling towers at 125 percent of system tonnage to allow for additional heat gain in the system due to mechanical work. A tower for an absorption system must be sized at 260 percent of actual tonnage. The rate for a 100-ton system using a motor-driven centrifugal compressor would be 125 tons. For a 100-ton absorption unit, the tower would be rated at 260 tons (100 x 2.6). In an absorption system the condenser water is used twice to remove equal heat from the absorber section (heat of absorption) and from the condenser section.

395 PROBLEMS OF COOLING TOWERS

395.1 Spillover

When the tower is operating, the makeup water float should be positioned so that there is no spillover into the overflow of the basin. This requires periodic checks to prevent wasting both water and the chemicals used in treating it.

395.2 Water Change

The water in the circulating system is affected by the natural impurities in the makeup water, the concentration of solids resulting from evaporation, and the presence of airborne particles washed out of the air as the water passes over the tower. To combat the change in water, chemicals are required. This is covered in detail in Chapter 4.

395.3 Wood Decay

The wood in the cooling tower becomes decayed or destroyed as a result of chemical or biological attack or by rupture of the wood cells from salt crystallization. Chemical attack results in delignification of the wood leaving long, stringy fibers of greatly reduced strength. Excessive use of chlorine seems to speed up the process. Biological attack includes fungi, destroying the wood both on the surface and from within. The fungi are reproduced from spores washed out of the air by the tower water. Rupture of the wood fibers of the tower by the crystallization of salts is caused by the intermittent splashing and drying of the wooden parts, producing concentrated salt deposits through evaporation.

395.4 Slime, Algae, and Fouling

.41 General. One of the worst problems with algae and slime is the fouling of the tower itself. Cooling efficiency of the tower is determined by the water-to-air contact surface, and the length of time water and air are in contact. When a tower is clean, the water will film out on the tower fill to make use of the total contact area. The air passages are clear and the maximum amount of air passes over or through the fill area. This results in maximum contact area and contact time between the water and air.

.42 Algae and Slime. If a tower has a heavy growth of algae or slime, the tower fill is soon covered by this growth. Other material is filtered out of the air by this sticky covering and a buildup of material is formed. This restricts the airflow through the fill area and reduces the filming action of the water. Tower efficiency goes down and the water temperature goes up. Algae grows on the exposed outside area of the fill and can completely block air from passing through the fill area. In order for a cooling tower to carry its share of the load, it must be clean and have an even flow of water and air throughout the fill area. If distribution basins are clogged with algae or other material, part of the tower fill does not receive its flow of water. This dry area offers less resistance to the airflow passing through the tower, so more air is pulled through the dry area, resulting in reduced airflow in the other areas.

.43 Other Material. Tower fouling is also caused by other material in the system and deposits of calcium carbonate, mud, or other airborne material usually found in the tower pan or sump. The cooling tower acts as a settling basin for undissolved solids traveling with the water. This is due to the relative quiet area of the tower with less velocity or movement of the water. This buildup of loose material settles in the distribution pans or on the wood slats of the packing and diverts or restricts water and air much like algae. The worst problem experienced in evaporative condensers is fouling by slime, scale, or other material. Because green algae is not a problem with indoor systems, and since the water is pumped from the basin back to the tip, there is no water problem, other than in the condenser itself.

395.5 Corrosion

.51 Cause. Corrosion is mainly caused by dissolved gases, aggressive water (low pH), bacterial attack, and dissimilar metals. A cooling tower or evaporative condenser increases the possibility of corrosion by increasing exposure to air.

.52 Gases. Dissolved gases that cause corrosion are usually oxygen, carbon dioxide, and sulphur dioxide. Sulphur dioxide usually results from burning coal or other fuels that contain sulphur or industrial plant fumes. Oxygen and carbon dioxide are common gases and are part of the atmosphere. The water in the tower system washes these gases from the air as the air passes through the tower packing, and circulating water carries large amounts of oxygen, carbon dioxide, and sulphur dioxide into the piping system. The amount of carbon dioxide and sulphur dioxide present in the water depends on the amount present in the air that goes through the tower. If the tower is picking up air close to a boiler stack or, if it is located in an industrialized area, the concentration of these gases may be quite high. When absorbed into water, the carbon dioxide gas forms carbonic acid; sulphur dioxide gas forms sulphuric acid. Either of these reduces the alkalinity of the water. If enough of the gases are absorbed into the system, the water becomes acidic and attacks and dissolves the metal in the system.

396 TROUBLESHOOTING GUIDE

Table 3-7, Troubleshooting Guide, lists the most common troubles that may occur in cooling towers. It includes the probable causes of the listed troubles and recommended remedies for their correction. Data in this guide is of a general nature and is intended to provide a standard approach to identifying and analyzing the most common troubles. It is recommended that this guide be reviewed at the local level and expanded, if necessary, to include the results of local experience.

NOTE

While performing troubleshooting procedures, observe all normal precautions for safeguarding personnel and equipment.

TABLE 3-7

TROUBLESHOOTING GUIDE FOR COOLING TOWERS

COMPLAINT	CAUSE	POSSIBLE REMEDY
1. There is excessive drift.	a. Faulty drift elimination	a. Check to be sure all eliminator slats are in place. Top deck assemblies and wood fill must be intact and level. There must be no tendency to channel water. There must be no leaks under basin sides.
	b. Overpumping	b. Reduce water flow to tower to design conditions.
2. Cold water is too warm.	a. Overpumping	a. Reduce water flow to tower to design conditions.
	b. Wood will not level	b. Check wood fill with carpenter's level traversely and longitudinally. Level if required.
	c. Wood fill not properly installed	c. Alternate decks should have been turned end for end.
	d. Not enough air	d. Check motor current and voltage to be sure of correct contract hp. Clean algae or muck from wood fill and eliminators.
3. There is unusual motor noise.	a. Motor running single phase	a. Stop motor and attempt to start it. Motor will not start if single phased. Check wiring, controls, and motor.
	b. Electrical unbalance	b. Check voltages and currents of all three lines. Correct if required.
	c. Ball bearings	c. Check lubrication. Replace bad bearings.
4. Motor runs hot.	a. Motor overload, wrong voltage, or unbalanced voltage	a. Check voltage and current of all three lines against nameplate values. Repitch fan blades if necessary.
	b. Bearings overgreased	b. Remove grease reliefs. Run motor up to speed to purge excessive grease.
	c. Excessive belt tension	c. Reduce tension and check shaft alignment.
	d. Poor ventilation	d. Clean motor and check ventilation openings.
	e. Wrong grease	e. Change to proper grease. See motor manufacturer's lubricating instructions.
	f. Winding fault	f. Check with ohmmeter.
5. Fan is noisy.	Loose bolts in fan guard	Check and tighten if necessary.
6. There is unusual fan drive vibration.	a. Loose bolts and cap screws	a. Tighten all bolts and cap screws on all mechanical equipment.
	b. Unbalanced fan	b. Be sure blades are properly positioned in correct sockets. (See match numbers.) All blades must be pitched the same.
	c. Unbalanced motor	c. Disconnect load and operate motor. If motor still vibrates, rebalance motor.
	d. Worn fan shaft bearings	d. Check bearings and mounting bolts.
	e. Bent shaft	e. Make sure fan and motor shafts are straight and properly aligned.
	f. Belts	f. Belts should be stretched to the proper tension.

CHAPTER 4

WATER TREATMENT

410 GENERAL

411 BACKGROUND

411.1 Definition

Water treatment is the control of dissolved gases and minerals normally present in water to prevent scale, corrosion, and microbiological growth from affecting mechanical systems that use water as a means of heat transfer. Water treatment is necessary when operating steam and hot-water boilers, air-conditioning systems using cooling towers, air-handling systems having wet wash, or any type of closed- or open-loop water system requiring makeup water.

NOTE

A glossary of important water-treatment terms is included at the end of this chapter.

411.2 Use

The goal of a water-treatment program is to alter the chemical content of the supply water to minimize corrosion and prevent scale deposits on the heat exchanger. The water-treatment program is also an effective means of preventing the formation of algae and slime. A basic knowledge of the types of chemicals used and an understanding of the various methods for introducing the chemicals into the water systems is essential for a successful water-treatment program.

WARNING

Make sure all chemicals, acids, testing reagents, etc., are properly marked and kept in a safe location so that no one will mistake their contents.

412 BIOLOGICAL FOULING

412.1 General

Microbiological growths are very small organisms like molds, bacterial slimes, algae, and bacteria. Some are dangerous to health, others cause bad taste and odors, and many produce clogging deposits. Biological fouling is a common problem in cooling towers and usually appears as algae and slime in the tower. Various other kinds of bacteria interact with iron and sulfur to cause corrosion and produce insoluble salts. These are usually carried to another part of the system and deposited as sludge. Algae consists of tiny cells that multiply and produce large masses of plant material in a short time. The growth is usually quickest in hot weather and bright sunlight. Slime consists of a gelatinous mass that clings to practically all surfaces in the system. It traps organic matter, debris, and scale-forming material. When microbiological growths break loose from the tower, they clog lines, pumps, and heat exchangers. The growth attacks and may destroy wooden parts of the cooling tower and reduce the heat transfer between the air and water in the tower.

412.2 Safety

Algaecides, slimicides, etc., used in the cooling tower to combat algae probably have a chlorine base. These chemicals give off chlorine gas. Some type of OSHA approved deluge shower and eye wash must be provided in the immediate area where water is treated.

413 CORROSION

413.1 General

Corrosion of metal piping systems and equipment is a very costly and serious problem. Corrosion not only eats away metal from the system, it deposits the resulting material at other locations. Corrosion products increase friction and pumping costs, reduce the capacity of lines, and may result in the complete blockage of a system.

413.2 Type of Corrosion

.21 **Basic Types.** There are five basic types of corrosion. All corrosion, although called by a special name, is one of these types.

.22 **Acidity.** Water with a pH reading below 7.0 results in a water solution that is corrosive to metal. The pH readings below 7.0 may be caused by sulfuric, hydrochloric, or nitric acids that enter the system through makeup or are chemically formed in the system from certain gases picked up from the air.

.23 **Oxygen Corrosion.** Oxygen corrosion is the main reason for boiler-tube corrosion, condensate return-line corrosion, closed-loop piping corrosion, and tower-system corrosion. Oxygen reacts with iron to cause iron oxide (rust). This usually pits the metal and bores small holes completely through the metal wall.

.24 **Galvanic Corrosion.** Galvanic corrosion is an electrical reaction between two different metals in electrical contact. Galvanic corrosion requires three factors to produce the action: two metals, an electrolyte, and a connection between the two metals. Galvanic corrosion usually results in pitting of the exposed metal.

.25 **Biological Action.** Biological action is pitting corrosion caused by metal-consuming bacteria, or by oxygen cell corrosion caused by algae, fungi, or slime sticking to metal. The slime releases oxygen into the water and the result is the same as oxygen corrosion. Other slimes combine with sulfates in the water to give off weak acids which attack the metal.

.26 **Erosion.** Erosion is the wearing away of metal surface due to water moving along it at high speeds. Erosion, or metal loss, is higher when gas bubbles or solids of any type are present in the water flow.

414 SCALE

414.1 General

Although scale is not normally considered a problem in low-pressure boilers, it sometimes does occur, reducing boiler efficiency or burning out tubes. Scale deposits are a very common problem in any open recirculating system that uses a cooling tower where a portion of the water is evaporated and must be replaced by makeup. Closed-loop systems that are properly maintained should never incur scale problems.

414.2 Definition

Scale is a material that precipitates from the water. It usually consists of calcium carbonate (limestone), calcium sulfate (gypsum), magnesium carbonate (magnesium), and silica (silicate). Calcium carbonate accounts for over 85 percent of all scale buildup in air-conditioning systems, but the scale may contain all of the above materials to some degree. The iron in ferric oxide comes from ferric oxide in the makeup water or from iron picked up from the system itself as a result of corrosion in another part of the system.

414.3 Formation

Scale is formed when dissolved mineral salts in the water become insoluble due to certain chemical and physical forces. The dissolved salts come out of the water as a solid and are deposited as scale or settle out as sludge. The inability of the dissolved material to remain in solution is the real reason for scale. The three main features that affect the rate of scale formation are temperature, pH, and mineral content of the water. Increasing any of these factors increases the probability of scale forming.

414.4 Effects

The main effect of scale is the loss of heat transfer and reduction of water flow. The result is higher system operating temperatures, inefficiency, and eventual shutdown of the system.

415 SLUDGE

Boiler water sludge is the soft, mud-like material that settles to the bottom of the boiler. It is removed by blowdown or by flushing out the boiler with water. It is a combination of mineral and organic matter that enters as part of the makeup water or is added to the boiler as part of the regular internal treatment. Sludge that settles on top of boiler tubes may have the water cooked out of it. This produces the same result as scale formation. Cooling tower sludge is similar to boiler sludge and is formed in the same manner, however, sludge found in a tower system is usually composed of a mixture of material from the makeup water and material that is washed out of the air stream as it passes through the tower.

416 CYCLES OF CONCENTRATION

The term "number of concentrations" is perhaps less confusing than "cycles of concentrations." Both terms refer to the ratio of dissolved solids in the recirculating system water to the dissolved solids in makeup water (see Part 456).

417 ACIDITY vs ALKALINITY (pH)

417.1 Measurement

Water is either acid, alkaline, or neutral. The control of acidity or alkalinity is an important aspect of the water-treatment program. The pH value is the measurement of acidity or alkalinity of the water.

417.2 pH Value

In practical application, the pH value of water is represented by a number between 0.0 and 14.0, indicating the degree of acidity or alkalinity. The midpoint of the scale is 7.0. A solution with this pH is considered neutral. Solutions with pH values below 7.0 are considered acidic and those with values above 7.0 are considered basic (alkaline). A pH below 7.0 encourages corrosion of equipment; a pH above 7.5 encourages the deposit of calcium carbonate scale.

```
                pH SCALE

    Acidity                Alkalinity
/_/_/_/_/_/_/_/_/_/_/_/__/__/__/__/
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
              !
           Neutral
```

Normal pH values are considered as follows:

a. Closed-Loop Systems (Hot-Water Heating and Chilled-Water Systems).

Normally, it is not necessary to treat closed-loop systems to control pH. A tight system should stabilize itself and have a pH value between 7.5 and 9.0.

b. Boiler Water (Steam Boilers). Water treatment is required to maintain a pH value of between 10.0 and 11.5 in boiler water.

c. Condensate Return (Steam Boilers). boilers). These generally do not require attention, but the pH should be at least 7.0 or slightly higher.

d. Cooling Tower System. Maintain a pH of 7.0 to 8.0 in the cooling tower or atmospheric-condenser system. If it is necessary to control factors other than pH and hardness, such as control of sodium hydroxide formation, pH may be carried lower or higher.

418 HARDNESS

Hardness of water is a problem in vessels in which water is boiled; scale in a tea kettle, for instance. To evaluate the effect of hardness in the operation of a cooling tower, note that hardness is a characteristic of water involving certain substances in solution and that the principal constituents causing hardness are calcium and magnesium. Hardness data is readily available from the local water supply company. The water-treatment program is related to the hardness of the supply water. The bleed rate is related to the hardness of the supply water.

420 BOILER SYSTEMS

421 HIGH-PRESSURE STEAM BOILERS

High-pressure steam boilers operate above 15 psig. Few postal facilities have high-pressure boilers and, due to the small number involved, treatment for high-pressure steam boilers is not covered in this handbook.

422 LOW-PRESSURE STEAM BOILERS

422.1 General

Low-pressure steam boilers are currently being replaced with hot-water boilers in postal facilities. Steam heating systems are more likely to have water treating problems than the hot-water heating systems. This part covers water treatment for steel boilers, firetube boilers, and cast-iron sectional boilers that operate below 15 psig and require very little makeup. Common chemicals and their use in boiler water treatment are shown in Table 4-1.

422.2 Scale

Scale is formed when minerals in the water precipitate out when the water is heated. When a boiler is filled with water, there is a certain amount of minerals that may form scale, but the amount is usually so small that it is not considered a problem. If no additional water is added to the boiler, the water in the boiler will drop out the small amount of scale-forming minerals and no further scaling can occur unless additional scale-forming minerals are added to the water. Since the heating system is similar to a closed system where the same water is used over and over, the only reason for adding additional water or makeup is to replace any water lost from the system due to steam leaks, pump-packing drip, vent-valves, blowdown, etc.. All loss of steam or condensate should be stopped, if possible, and blowdown used only if absolutely necessary. Blowing down a boiler results in adding makeup containing more scale-forming minerals. The only method to determine if blowdown is required is to test the boiler water. This requires special test equipment not normally available in small offices.

TABLE 4-1

COMMON CHEMICALS USED IN BOILER WATER TREATMENT

CHEMICAL	PURPOSE	COMMENT
Sodium hydroxide NaOH (caustic soda)	Increase alkalinity, raise pH, precipitate magnesium	Contains no carbonate, so does not promote CO_2 formation in steam
Sodium carbonate Na_2CO_3 (soda ash)	Increase alkalinity, raise pH, precipitate calcium sulfate as the carbonate	Lower cost, more easily handled than caustic soda. But some carbonate breaks down to release CO_2 with steam.
Sodium phosphates NaH_2PO_4, Na_2HPO_4, Na_3PO_4, $NaPO_3$	Precipitate calcium as hydroxyapatite ($Ca_{10}(OH)_2(PO_4)_6$)	Alkalinity and resulting pH must be kept high enough for this reaction to take place (pH usually above 10.5).
Sodium aluminate $NaAl_2O_4$	Precipitate calcium, magnesium	Forms a flocculent sludge.
Sodium sulfite Na_2SO_3	Prevent oxygen corrosion	Used to neutralize residual oxygen by forming sodium sulfate. At high temperatures and pressures, excess may form H_2S in steam.
Hydrazine hydrate $N_2H_4 \cdot H_2O$ (35% solution)	Prevent oxygen corrosion	Removes residual oxygen to form nitrogen and water. One part of oxygen reacts with three parts of hydrazine (35% solution).
Filming amines, octadecylamine, etc.	Control return-line corrosion by forming a protective film on the metal surfaces	Protects against both oxygen and carbon dioxide attack. Small amounts of continuous feed will maintain the film.
Neutral amines Morpholine, Cyclohexylamine, Benzylamine	Control return-line corrosion by neutralizing CO_2 and adjusting pH of condensate	About 2 ppm of amine is needed for each ppm of carbon dioxide in steam.
Sodium nitrate $NaNo_3$	Inhibit caustic embrittlement	Used where the water may have embrittling characteristics.
Tannins, starches, glucose, and lignin derivatives	Prevent feed line deposits, coat scale crystals to produce fluid sludge that will not adhere as readily to boiler heating surfaces	These organics, often called protective colloids, are used with soda ash, phosphate. They distort scale crystal growth and help inhibit caustic embrittlement.
Seaweed derivatives (sodium alginate, sodium mannuronate)	Provide a more fluid sludge and minimize carry-over	Organics often classed as reactive colloids, since they react with calcium, magnesium, and absorb scale crystals.
Antifoams (Polyamides, etc.)	Reduce foaming tendency of highly concentrated boiler water	Usually added with other chemicals for scale control and sludge dispersion.

422.3 Corrosion

.31 **General.** Proper treatment is required to prevent or control corrosion in low-pressure boilers. All raw water contains impurities, including dissolved gases such as oxygen and carbon dioxide. Depending on the source of the water (lake, river, well, etc.), the water may be corrosive as received, or it may turn corrosive after it enters the system. Corrosion attack may be general throughout the boiler or may be localized pitting.

.32 **Oxygen Corrosion.** Pitting is usually the form of corrosion resulting from oxygen in the water. This is the worst type of corrosion, since it may create small hidden holes in a pipe or tube on the water side in a very short time. Oxygen enters the boiler with makeup water or with the condensate return. Oxygen corrosion in a steel boiler is usually discovered when the boiler tubes start leaking. Visual inspection is the only way to tell how much damage has been done. The corrosion area might be small or it may cover the entire area of the boiler. Oxygen is sometimes picked up at the condensate-return tank and, when this happens, the piping between the condensate pump and the boiler is the first to leak. Rusty water in the boiler is a certain indication that corrosion is taking place somewhere in the boiler or system. The corrosion cells are usually seen as small blisters, or deposits, on the boiler tubes or walls and, when the metal deposit is brushed off, it reveals pitting in the metal. Oxygen can also cause pitting corrosion without the depositing of material.

.33 **Return-Line Corrosion.** Pure condensate does not conduct an electric current and, even though it contains dissolved oxygen, does not cause corrosion. This is the reason that some plants have operated for years without treatment and have no problem with return-line corrosion, while other plants have to replace piping during the first year of operation. If no carbon dioxide (CO_2) is produced in the boiler or admitted to the system and if the steam condensate is kept pure of contaminators by preventing water carry-over from the boiler, return-line corrosion is usually not a problem.

422.4 Sludge

.41 **Frequency.** In low-pressure boilers, sludge is as unusual as scale. Sludge comes from material in the make-up water and from chemicals used as treatment. If large amounts of makeup are required, larger amounts of chemicals are required forming larger amounts of sludge. Keeping the system tight and eliminating the need for make-up eliminates sludge problems. Sludge is removed by a bottom blowdown and a chemical treatment that conditions it to form in soft masses and settle to the bottom of the boiler.

WARNING

Steam valves, or any valve under pressure, must never be opened quickly. Use a bypass, if provided, or open the valve slightly and wait for the pressure to equalize.

.42 **Treatment.** Tannin is the chemical recommended for sludge conditioning in low-pressure steam heating boilers. Because it has proved to be the most satisfactory in sludge control, Quebracho Tannin is the only approved type of tannin. A light brown or "tea" color is maintained in the boiler water by the addition of Quebracho Tannin, but, unless the proper pH is also maintained, the tannin provides poor results. In addition to maintaining sludge in suspension, the tannin helps to control pitting and corrosion. It also tends to coat the boiler metal, which reduces the possibility of oxygen corrosion. Use the brown color imparted to the water as a simple field check for proper treatment level. Quebracho Tannin is available from area supply centers under Item C-1838.

422.5 pH

Low-pressure steam boilers are maintained in the pH range of 10.0 to 11.5. This level must be maintained to eliminate precipitation of calcium carbonate and magnesium hydroxide and to prevent scale from forming. The high pH reduces the possibility of corrosion occurring in the boiler. The chemical used to raise the pH to the desired level is caustic soda (lye).

WARNING

> Caustic soda reacts strongly when added to water. The solution can cause serious burns. Caustic soda must be added very slowly to water and the solution must be allowed to cool before handling the container. Always wear protective clothing when handling chemicals.

422.6 Return Line

Scale deposits rarely occur in the return system. When the system contains a constant amount of carryover from the boiler water, it may cause coagulation clogging of small lines or fittings, but not scale. Corrosion is the main problem encountered in return systems and usually results from an acid condition of the steam condensate (pH below 7.0), or a combination of oxygen and boiler water impurities that are carried over with the steam. The low pH of steam condensate usually results from carbon dioxide (CO_2) gas leaving the boiler with the steam and uniting with the condensate, forming carbonic acid that lowers the condensate pH level. Some CO_2 gas is produced in the boiler by treatment reaction. (For example, soda ash, which is used by many companies for water treatment, releases large amounts of CO_2 gas.) Oxygen pitting is more of a problem than acidic attack because it cannot be kept out of the return system in most plants. A steam boiler with impure steam, resulting in foaming and carryover, is much more likely to experience corrosion in the return system than a system with good steam purity.

The main causes of carryover are too high a water level, dirty boiler water, boiler overload, changing load, or over-firing. All of these cause the steam to carry material picked up from the boiler water. Treatment for return-line corrosion is not recommended for low-pressure heating boilers unless it is determined that a definite need exists. Proper operation and a good water-treatment program are the main requirements for a trouble-free system.

423 TESTING

423.1 General

Perform and log water testing as prescribed by the manufacturer of the chemicals used. In most instances, the chemical companies have a chemist to help set up a testing program that will ensure proper use of the chemicals. He can also recommend an installation's appropriate testing equipment.

423.2 pH

If a test kit for pH is available, use it to check the boiler water. If a test kit is not available, determine the pH with pH test strips such as "pHydrion test strips." These are purchased locally and come in different pH ranges. A strip that checks from 10.0 to 12.0 pH is ideal. Dip the paper strip into a sample of the boiler water and then match the color with the color chart on the container. Test only after any treatment is added and has dissolved and mixed with the boiler water. The pH should be maintained between 10.0 and 11.5. When testing indicates additional treatment is required, use caustic soda (lye) to raise the pH close to the 11.5 level. This reduces the need for treatment. Take the water sample from the water-column drain after all sludge or dirty water is drained off and collect it in a clean glass container. The pH reading can be made as soon as the sample is cool enough to handle.

WARNING

Take care not to burn the skin by hot water or flashing steam. Learn the location and function of every valve on the system and use try cocks when in doubt about true water level.

423.3 Tannin Content

Tannin content is determined by observing the sample used in the pH test. The water should look like weak tea and have a light brown color. Although most installations are not equipped to check tannin content by actual water analysis, the recommended level of tannin is 20 to 40 ppm. Tannin is a high-priced chemical. Use it sparingly.

424 TREATMENT METHODS

424.1 Small Heating Boilers

Properly maintained small steam-heating boilers (almost 100-percent return with little makeup) require only annual treatment. Bottom blowdown is not required. After the boiler has been cleaned, inspected, and refilled for summer lay-up, add treatment through the manhole. Prepare the caustic soda and tannin in separate containers and then add them to the boiler before it is fired to reduce the oxygen content. Once the boiler is properly treated and laid up, it can be serviced when needed by simply draining the water down to the operating level.

424.2 Boilers Requiring Makeup

Any boiler that requires a lot of makeup will also require a lot of treatment and attention. Makeup greatly enhances the probability of corrosion, and unless the loss of water can be stopped, the system may require additional types of treatment. Steam boilers usually require small amounts of makeup to replace what is lost from the boiler by such actions as blowdown, but when a boiler requires constant makeup, the reason must be immediately determined. If it is necessary to treat the boiler during the heating season, a simple pot feeder is installed on most boilers for adding treatment. These feeders are inexpensive and can be installed by local personnel. Other methods of installing treatment are using the condensate return tank or by installing a simple pipe funnel at the steam gauge connection. All treatment should be followed by clean water to flush all the treatment into the boiler. Never add treatment by using the safety valve hole.

NOTE

Manually check the boiler safety valves and safety relief valves every month while the boiler is under pressure.

424.3 Boilers With Automatic Makeup Valves

When two boilers, connected in parallel, are both operated at the same time, one boiler may supply the makeup for both boilers. This causes a difference in the treatment level of the two boilers, as do different firing levels. When two boilers are used on one system, check and treat each boiler separately.

WARNING

Never bypass or jumper automatic controls or safety devices.

430 HOT-WATER HEATING SYSTEMS

431 LOW-TEMPERATURE SYSTEMS

Low-temperature hot-water systems are closed circulating systems designed to operate with no leakage from the system and no makeup water. For postal installations, low-temperature hot water is defined as water temperature below 212 °F at the boiler outlet, regardless of the pressure. This type of heating system is standard in all new or remodeled postal facilities.

432 SCALE

Except for very unusual circumstances, there should be no problem with scaling in a hot-water system. Only a continuous loss of large amounts of system water and extremely bad makeup water would produce scale in these systems. Corrosion products are sometimes referred to as scale, but they are mainly iron products from the piping system and not from the water itself.

433 CORROSION

All makeup water contains oxygen that unites with metal to form rust or corrosion. Whenever water is added to the system, a certain amount of corrosion will occur unless something is done to prevent it. For every 20 °F rise in the temperature of the water, the corrosion rate of the water doubles. Therefore, water at 180 °F is twice as corrosive as the same water at 160 °F. This is especially important if corrosion is known to be a problem in a hot water system. When the heating system is filled the first time with raw or untreated water, oxidation or rusting takes place until all of the oxygen in the water is gone or has combined with the metal to produce rust. If the system is tight and no water is lost and no air or water is allowed to enter the system, treatment is not needed. Many hot-water heating systems operating without any type of treatment have no corrosion problems, because the amount of corrosion due to the initial water charge is very small. The real problem is the oxygen and dissolved gases brought into the system by makeup due to water leaks or improper design or operation. Very few hot-water heating systems are truly closed systems that require no makeup.

434 MAKEUP

Makeup must be added to all systems in a way that prevents any possibility of backflow of boiler water and chemicals into the water-supply line. To do this, a device, commonly referred to as a "vacuum breaker," or "backflow preventer," is used. State and local building codes require these devices to be installed to prevent the contamination of the city water. When water is cold, the pressure in the expansion tank may drop low enough to permit the admission of makeup water into the system. When the water temperature increases, the system pressure further increases due to expansion of the additional water in the system.

NOTE

Learn the location and function of every valve on the system.

435 CLEANING HOT-WATER SYSTEMS

435.1 General

Cleaning a hot-water system consists of draining the system completely and giving the boiler a thorough internal cleaning. Make sure that all valves in the system are open so that all areas are thoroughly flushed. Consult your chemical supplier for a suitable treatment for cleaning hot-water systems.

NOTE

Maintain a written log or record of all events. Advise a supervisor of any change in operation or readings.

435.2 Operation

Start the boiler and pump and bring the solution to normal operating temperature and pressure. Maintain for 4 hours while the solution circulates through the system. The boiler is then cut off and the temperature is allowed to drop to about 120 °F. The pump is cut off and the entire system drained. Low points in the system should be flushed, if possible, to remove any material that has settled out. The system is again filled and vented for normal operation. If needed, the system may then be returned to normal service; if the system is not needed, it should be started and the boiler water allowed to circulate for at least 1 hour.

435.3 Treatment Program

A good chemical treatment program usually precludes the need for cleaning and flushing. The chemical supplier's representative knows requirements for cleaning. Check the pH of the water and, if it is low, trisodium phosphate can be used to raise the pH to between 8.0 and 9.0. If an inhibitor-type treatment is used, treatment to the proper level will probably raise the pH to the desired level.

435.4 Water Capacities

The quantity of water in a system must be known to determine the proper amount of treatment to be used. A small water meter used when filling the system is the best method for determining water capacity of a heating system. The meter can be used on other systems in the same manner.

436 HOT-WATER SYSTEMS TREATMENT

436.1 General

Maintain the pH of the water between 8.0 and 9.0. Use caustic soda, trisodium phosphate, etc., to raise the pH if required.

WARNING

When used in boiler treatment, caustics and acids both create boiling temperatures when mixed with water. Both cause serious burns to skin and eyes and are fatal if swallowed. Safety goggles, rubber gloves, and aprons must be worn when exposed to caustics, acids, or chemicals. Use other protective clothing or gear as appropriate.

Protective garments are frequently worn to prevent dermatitis when using chemicals such as cleaning solvents. Leaking or permeable garments can increase the possibility of dermatitis by allowing the chemical to reach the skin and holding it there. Prior to use, inspect the garments for holes, breaks, or physical deterioration. If any are found, replace the garment. Do not use any garments that have a chemical odor inside. The odor is a sign that the garment material is incorrect for the chemical. To verify that the garment material and chemical are compatible, consult the information that comes with the garment or the garment manufacturer. (For example, garments made with Vitron elastomer have been shown to provide the best protection against 1, 1, 1, trichloroethane.) Postal safety and health personnel can provide technical assistance on hazardous properties of material and protective equipment.

436.2 Sodium Sulfite

Sodium sulfite, an "oxygen scavenger," eliminates oxygen by combining with it to form sodium sulfate, a compound chemical that does not affect the system. Since corrosion is the main problem in a hot-water heating system and oxygen attack is the main cause of corrosion, sodium sulfite is an effective method of treatment. Since the amount of sulfite required will depend on the amount of water and oxygen in the system, some type of check is necessary to make sure the system is properly treated. The best method of determining corrosion protection is to check the water for sodium sulfite content. Since sulfite and oxygen combine to form sulfate, any sulfite found in the system shows that there is more than enough treatment in the system. The presence of sulfite in a system indicates the oxygen has been removed.

436.3 Inhibitors

.31 **Use.** Another treatment method used in closed-loop hot-water heating systems is the use of an effective corrosion inhibitor. The inhibitor reduces corrosion by forming a coating on all metal surfaces but does not produce any chemical changes in the water.

.32 **Chromates.** Do not use chromates that may be drained into a local sewer system unless a local authority operates a chromate removal program and allows their use. If chromates are used, the treatment must be a low-level type and not exceed 50 parts-per-million (ppm) in any system.

WARNING

Exercise extreme caution when using chromates.

.33 **Types.** There is no one type of inhibitor used in hot-water systems. Inhibitors formulated for closed-loop systems are also used in other systems. The same treatment may require different levels of concentration in different types of systems. Almost all chemical-treatment companies treat standard chilled-water and hot-water heating systems with the same inhibitor. However, a nitrite-base inhibitor is considered one of the best treatments for hot-water heating systems. (See Section 446.2.)

437 SULFITE TESTING

If sulfite is used to treat hot-water heating systems, the pH and sulfite level in the water must be controlled. The frequency of these checks depends on the amount of water added to the system as makeup. A system with leaks may require testing and treating once a month. A system with no loss of water and no requirement for makeup can probably be checked and treated once a year. The representative of the chemical supplier knows how often to test the treatment level and what equipment is required. The pH can be checked with pH test strips, titration, or a colormetric kit. Some large offices use portable or built-in electric pH meters with a strip recorder. The pH should be maintained between 7.5 and 9.0. An excess of sodium sulfite should be maintained between 20 and 40 ppm. A drop in sulfite content in the system is a sure sign of leaks. With a sulfite test kit, check the sulfite by a simple titration method. Exposing the water sample to the air destroys the test accuracy as sulfite will combine with the oxygen in the air and convert to sulfate. Follow instructions closely when collecting a water sample for sulfite testing.

NOTE

If the system is treated with an inhibitor, testing is the same as described in Part 447.

438 TREATMENT METHODS

Large systems are now installed with a built-in bypass feeder for treating the water. Small systems and many GSA-installed systems do not have any type of treating equipment. If the system is treated only once a year, it is not necessary to install a feeder because the chemicals can be added by hand before the system is placed into operation at the beginning of the fall season. However, the type of treating equipment required depends on many things, such as the type of material to be added to the system, the amount of material, how often treatment is required, how critical the water-treatment range is, and what reduction in workhours will result from installing new equipment.

440 CHILLED-WATER SYSTEM

441 GENERAL

There are two types of chilled-water systems: a closed system where the entire system is under pressure, with a sealed expansion tank compensating for the expansion due to water temperature changes; and an open system where the chilled water is used as an air-wash system. The standard system installed in postal facilities is a closed-recirculating system. Except for the difference in temperature, the chilled-water system is identical to the hot-water heating system.

442 SCALE

Unless a system uses an excessive amount of makeup, there should be no scale in the system.

443 CORROSION

Due to the lower operating temperature, corrosion is less likely to occur in a chilled-water system than it is in a hot-water system, but it should be considered when treating the system. Dissolved gases are the main cause of corrosion, and oxygen is the worst offender.

444 WATER LOSS

Water lost from the system must be replaced with fresh water. This brings in additional oxygen and other dissolved gases which, without treatment, will combine with the iron piping and produce rust or flaking of the metal walls. Stopping all leaks to prevent loss of water is the best method to stop corrosion in the system.

445 CLEANING THE CHILLED-WATER SYSTEM

When required, a chilled-water system is cleaned in the same manner as hot-water heating systems. The water temperature should be maintained as high as possible during the cleaning operation, so the chiller units should be off, and the temperature of the water allowed to rise before the cleaning operation is started.

NOTE

Always follow all existing safety regulations.

446 TREATMENT

446.1 pH

The pH level should be maintained between 7.5 and 9.0, but chemical treatment is usually not necessary to maintain this level.

446.2 Inhibitor

Use a corrosion inhibitor that protects the metal surface against corrosion by forming a protective coating or film on the metal surface. This film protects against the dissolved gases in the water (usually oxygen). In hot-water systems, sodium sulfite is used to combine with the oxygen to produce sodium sulfate. Due to the low temperature of the chilled water, this does not work. A nitrite-base inhibitor is the best. It works very well on iron and steel and can be combined with other inhibitors when copper or aluminum is present in the system. The nitrite material does not stain and is compatible with all types of antifreeze solutions.

There are many blends of nitrite-base inhibitors on the market, and, until an all-purpose blend can be developed, formulated nitrite-base inhibitors should be purchased from chemical companies. Maintain the treatment levels prescribed by the company.

447 TESTING

Conduct control tests often enough to ensure that pH and inhibitor level is being maintained. (This ranges from once a month to once a season.) The required test for inhibitor control is determined by the treatment used, but will probably be a test for ppm of nitrite. The chemical supplier knows the proper testing procedure and the frequency to ensure satisfactory chemical level in the system.

448 TREATMENT METHODS

All closed-loop systems use the same treatment methods. Follow the treatment directions in Part 438. There should not be a need for any type of automatic feeding or checking equipment on a closed-loop system. A bypass feeder is the ideal equipment, but many offices prefer the simple one-shot or pot feeder.

450 COOLING-TOWER SYSTEMS

451 GENERAL

All cooling towers operate on the principle of evaporation as described in Section 393.5 The initial cost of a cooling tower is high, but, when operated and maintained properly, cooling towers provide years of service and pay for themselves many times over. Most problems affecting towers are a result of mechanical neglect and improper water-treatment programs. Towers that should have operated for many additional years are replaced each year due to neglect.

WARNING

> Never allow anyone to go inside a cooling-tower system without "locking out" and "tagging" all associated equipment. Use Form 4811, Equipment Lockout Tag, to tag equipment that has been locked out.

452 BIOLOGICAL FOULING

Since a cooling tower depends on the evaporation of water to cool the remaining water, it is essential that nothing interfere with the evaporation process. When hot water enters the tower, it is directed through a distribution system to flow down through the tower in a uniform pattern that covers the entire fill area. As the water flows over the fill or packing, it is broken up and films out on the fill material. This provides the maximum contact surface exposed to the air stream through the tower. The air movement is also controlled so that an even flow of air travels through the fill area. The amount of surface where the water film and air come in contact determines the capacity of the tower. Anything (such as biological fouling) that reduces the filming action of the water, or alters the path or amount of air movement, reduces the capacity of the tower.

453 FOREIGN MATERIAL

Tower fouling also is caused by foreign material in the system. Deposits of calcium carbonate, mud, and airborne material are usually found in the tower sump. The cooling-tower sump acts as a settling basin for undissolved solids traveling with the water and buildup loose material that settles out in the distribution pans or on the wood slats of the fill. This has the same effect as algae, restricting or diverting water or air. The evaporative condenser has the same problems as the cooling tower, except that green algae is not a problem with indoor systems. Since the water is pumped from the basin back to the top, there is no water problem other than in the condenser itself. Fouling with slime, scale, and other material is the worst problem experienced with the evaporative condensers.

NOTE

Maintain a written log or record of all events. Advise a supervisor of any change in operation or readings.

454 CORROSION

454.1 Cause

Corrosion is caused by dissolved gases, aggressive water (low pH), bacterial attack, and dissimilar metals.

454.2 Dissolved Gases

The dissolved gases that cause corrosion are usually oxygen, carbon dioxide, and sulfur dioxide. Sulfur dioxide is usually a result of burning coal or other fuel that contains sulfur, or the operation of nearby industrial plants. Oxygen and carbon dioxide are common gases and are part of the atmosphere. These gases are absorbed from the air as the water passes through the tower fill. The circulating water then carries the oxygen, carbon dioxide, and/or sulfur dioxide into the piping system. The amount of carbon and sulfur dioxide present in the water depends on the amount present in the air that goes through the tower. If the tower is located close to a boiler stack or in an industrialized area, the amount of these gases may be quite high. When carbon dioxide is absorbed into water, carbonic acid is generated; when sulfur dioxide gas is absorbed into water, sulfuric acid is generated. Either of these acids reduces the alkalinity and pH of the water. If enough of the gases are absorbed into the system, the water will drop in pH until it is acidic and becomes aggressive. It will then attack and dissolve metal in the system.

454.3 Oxygen

Oxygen in the water attacks the metal and causes oxygen corrosion that either destroys the entire piping system in a short time or causes general corrosion throughout the system.

454.4 Bacteria

The constant supply of air and makeup water in the tower causes bacterial attack. Slime and algae growing in the tower end up in the piping system and increase the corrosion problem by forming oxygen corrosion cells.

455 SCALE

455.1 Cause

Scale is the largest problem associated with cooling towers. It is mainly caused by the gradual buildup of minerals and other material in the water due to the evaporation taking plate in the tower. Some makeup water is so high in scale-forming material that scaling would result if the water was used once and discarded. When this type of water is used in a cooling tower (where the concentrations are further increased), the scaling problem becomes severe. Due to its inability to stay in solution in hot water, calcium carbonate (limestone) is the chief producer of scale in a system. As the water temperature goes up, the ability of calcium carbonate to stay in solution diminishes, and it is deposited on the hottest surface as a white powder or soft scale. Thus, scale is more pronounced in the hot end of the condenser.

455.2 Scaling Materials

Most scale in tower systems is actually a combination of several materials, but generally consists mostly of calcium carbonate. Other scaling materials are calcium and magnesium silicates, and calcium sulfate. If phosphate treatment is used and the system is overtreated, phosphate scale may be precipitated in the condenser or elsewhere in the system.

456 CYCLES OF CONCENTRATION

456.1 General

Cooling-tower cooling is accomplished through the evaporation of water. As water is evaporated, the minerals are left behind in the cooling-tower water. Thus, the hardness of the remaining tower water is increased. The resulting increase in hardness is often described as the number of "cycles of concentration" of the tower water.

456.2 Number of Cycles

The cycles of concentration help in comparing the dissolved solids in the circulating water with those in the makeup or raw water. If, as a result of evaporation, the solids in the tower water become twice as great as those in the makeup, there are said to be two cycles of concentration. Three times as many solids would result in three cycles of concentration; four times would be four cycles, and so on. The maximum allowable cycles of concentration are predetermined by analysis of the makeup water and other factors. After a plant is placed in operation, increasing the bleed rate will lower the cycles of concentration; reducing the bleed rate will increase the cycles. Since all minerals found in the makeup water increase in content as water is recirculated and evaporated in an open-spray system, it must be determined which mineral will be used to determine and control the number of cycles.

456.3 Use of Chlorides

Chlorides are salts that have the ability to become concentrated in large amounts in water without precipitation taking place, except in conditions not encountered in air-conditioning system towers. This is the reason chlorides are normally used as the element to control blowdown or to maintain concentration levels. If, for example, a system is maintained at four cycles of concentration, and a check on makeup water shows 100 ppm total hardness and a check of tower water shows 375 ppm total hardness, this is only 3.75 cycles of hardness; so the concentration level could still be increased without laying out scale. Do not depend on this test alone; use at least one other test, such as the one for chlorides. If chlorides are also checked and 45 ppm of chlorides are found in the tower water and 10 ppm of chlorides in the makeup water, 4.5 cycles of chloride concentration would be present. This test shows that the water is oversaturated and means that, unless chlorides are being picked up from some other source, the water actually contains 4.5 cycles of concentration and something has happened to the hardness. Further tests would be more conclusive, but, based on the two tests alone, it is obvious that part of the minerals contained in the water has precipitated out as scale. The installation of an automatic blowdown control in lieu of continuous bleed off should be considered. This device continuously monitors the dissolved solids and opens a blowdown valve when the dissolved solids reach a preset level. The big advantage of the automatic blowdown over the continuous bleed off is that it automatically adjusts to various load conditions. Water-treatment chemicals are added to the tower water to keep the minerals in suspension at the higher concentrations and not precipitate out on the surfaces of the condenser tubes. The suspended solids are drained to the sewer whenever the number of concentrations exceed the predetermined number. New makeup water is then brought in to maintain the cooling-tower water level.

Since 4.5 cycles of hardness would total 450 ppm, and the test only revealed 375 ppm, the other 75 ppm must be laid out as scale and is calcium carbonate scale. The main point here is that chlorides are the most stable materials for determining hardness of the water, so they are used when controlling cycles in tower or evaporative-condenser systems by bleed off.

456.4 Scale

.41 Allowable Cycles of Concentration. As already determined, the main effect of high concentrations in tower water is the formation of scale. When starting up a new system that has not been checked for allowable cycles of concentrations, tables 4-2A and 4-2B should be used as the method to initiate a blowdown or bleed off from the system. Table 4-2A shows allowable cycles of concentration based on the hardness of local makeup water. The cycles shown here are to be maintained in treating the system. Without any type of treatment (such as phosphate crystals), the allowable cycles would have to be reduced to maintain a scale-free system. After the allowable cycles are determined, the bleed can then be set to maintain this level.

.42 Softening Equipment. In arid locations or locations with very hard water, consider the installation of softening equipment for the makeup water. The cold process lime, lime-soda process, lime-gypsum process, or the zeolite process is recommended. It should be noted that this equipment is expensive and a careful consideration of all factors must be included in preparing an economic analysis. Consultation with a local water-treatment specialist is recommended. Suggested cycles of concentration are shown in Table 4-2A.

TABLE 4-2

CALCULATIONS FOR BLEED RATE

A. Hardness Relationship

Hardness of Local Water	Allowable Cycles of Concentration
Soft water - less than 60 ppm	5
Medium hard - 61 to 120 ppm	4
Hard - 121 to 180 ppm	3
Very hard - 181 and over ppm	2

Table 4-2B can be used by systems having capacities up to 100 tons.

B. Bleed Rate[1]

	Hardness of Local Water				
p.p.m.	Under 60	60-120	121-180	Over 180	NOTE
Bleed rate (gallons per hour)	3	5	7	16	Bleed should operate only when cooling tower pump operates

[1]Based on 10-ton system. For larger systems adjust the bleed rate proportionally.

Bleed rate for systems over 100 tons can be determined by using the equations shown in Table 4-2C.

TABLE 4-2 (Continued)

CALCULATIONS FOR BLEED RATE

C. Tonnage and Bleed Formulas

1. Actual Machine Tonnage = $\frac{gpm \times TD}{24}$ (chill-water gpm)

2. Tower Tonnage = Machine tonnage x system % (1.25% electric motor)
(1.67% steam turbine)
(2.6% absorption)

3. Evaporation in gph = tower tonnage x 1.8 or approximately 2 gph per ton

4. Blow down required = evaporation in gpm divided by number of required cycles minus 1. This can be stated:

$$B = \frac{E}{N-1}$$

Cycle = 100 percent of amount in makeup water (chlorides, TDS, hardness, calcium, etc.)

Tower basin content = approximate water evaporated every 2 hours

5. 1 lb. water evaporated = 970.4 Btu (approx. 1,000) or
100 lb. water lowered 10 ^{o}F = 1 percent

1 gallon water evaporated = 100 gallons water lowered 10 ^{o}F = 1 percent

To figure gallons in tower sump or square tank:

Width x length x depth (all in feet) = cubic feet of water
Cu ft x 7.5 = gallons

For total gallons in system (approximate) add 10 percent of sump content for each 50 feet of pipe between tower and condenser. (Figure footage of both pipes.)

Note: For absorption systems, in addition to above add the following for each machine:

1/2 machine tonnage + 30 = gallons in machine

To find content of round tanks:

Diameter in ft. squared x length (ft) x 6 = gallons water

To estimate chill-water gallons:

100 gallons chill water for each 10 tons of machine tonnage

6. C = Circulating rate in gpm. 3 gpm/ton or 3.5 to 4 gpm/ton for absorption
E = Evaporation. 1 percent of C for each 10 ^{o}F range in tower water temperature.
B = Bleed
W = Wind loss or drift usually ignored in mechanical towers
M = Makeup (total) combination of E & B
N = Number of cycles of concentrations

The above figures are used in the following. Any two will find a third.

$N = \frac{M}{B}$ $B = \frac{M}{N}$ $B = \frac{E}{N-1}$ $M = \frac{N}{E \times N-1}$ $M = E + B$

457 ALKALINITY

Reducing the amount of alkalinity in a tower system can be accomplished by increasing the bleed rate, but a large amount of water would have to be bled off. Sulfuric acid treatment is another method used in large systems. The acid converts the scale-forming calcium carbonate to a more soluble calcium sulfate and, as the alkalinity is reduced, so is the scale-forming tendency of the water. If the amount of calcium sulfate in the makeup water is high, the use of sulfuric acid may not be feasible, as its use would further increase the levels of calcium sulfate which also has a saturation level that cannot be exceeded without laying out a sulfate scale. Sulfuric acid also reduces the pH level of the water by increasing the hydrogen ions. Hydrochloric acid is sometimes used to reduce the alkalinity when it is not feasible to increase the calcium sulfate level by the use of sulfuric acid. During temporary water shortages, treatment can be increased beyond normal to allow operation with increased cycles of concentration and reduced bleed off. Only under extreme conditions should bleed off be reduced below the safe level to prevent scale formation with maximum chemical treatment.

458 TOWER WOOD

458.1 Delignification

By leaching out the soft lignin material, chemical attack causes delignification of the tower wood, leaving long stringy wood fibers, called cellulose, as the only means of support. The strength of the lumber is reduced and the wood surface is more vulnerable to further destruction by biological attack. The use of makeup that has been softened by the zeolite process causes delignification to occur. This is caused by a high sodium carbonate level in the water. Use of chlorine as a treatment for slime and algae is another common practice that causes destruction of lumber in the tower as does a pH level above 8.0. High alkalinity levels and high levels of dissolved solids are other causes of delignification.

458.2 Wood Rot

.21 **Definition.** Wood rot is the common name for biological attack of lumber. It occurs on the surface and inside wood. Usually fungi, reproduced from spores which are washed out of the air by the tower, are responsible for wood rot. The fungi use cellulose from the wood for the carbon essential to their growth and development. Surface rot is more apparent in the flooded portions of the tower; internal rot is more apparent in the wood members that are not covered by a film of water. Oxygen is also a requirement for growth and the flooded areas prevent oxygen from entering the wood, however, enough oxygen is present in the water to support surface growth of the fungi.

.22 **Salt Definition.** Salt deposits resulting from evaporation also subject the wood fibers to rupture. Crystallization of salts is caused by intermittent splashing and drying of the wood.

.23 **Severity.** Wood towers that have a life expectancy of 20 to 25 years are frequently partially or totally replaced in 10 years or less, due to wood destruction from chemical or biological attack.

458.3 Treatment

Control of wood deterioration starts before the cooling tower is put into operation. All wood used in the tower that has not been pressure-treated at the factory should be sprayed on-site with a wood preservative such as creosote. Pressure-treated lumber ensures many years of protection against biological attack. Other methods used to protect the tower are the following:

a. Maintain pH below 8.0 and, if possible, between 6.0 and 7.0.

b. Use nonoxidizing slimicide.

c. At least once a year spray areas showing biological attack with a good fungicide.

d. When chlorine-based material is used, do not exceed 1.0 ppm of chlorine.

e. Thoroughly inspect the tower each year.

f. Replace all damaged wood with pressure-treated wood.

459 EVAPORATIVE CONDENSERS

459.1 General

An evaporative condenser is made up of hot-gas tube banks. Water is sprayed over the coils to remove the latent heat of condensation. A portion of the water evaporates as the water passes over the condenser coils. The evaporation cools the remaining water; absorbing heat from the tube surfaces. The major difference between the cooling tower and evaporative condenser is that the tower is filled with material that exposes the water to the air stream, while the evaporative condenser uses the condenser coils as the filming area.

459.2 Problems

Evaporative condensers experience the same general problems as cooling towers and are treated and maintained in the same manner. Algae and slime present the same problem as encountered in the tower. Corrosion and scale are more apparent than in the tower; all corrosion and scaling being on the outside of the system rather than inside the piping and condenser as in the tower system. Scaling is more of a problem in an evaporative condenser than in a tower system. Due to the higher temperature of the hot-gas piping, calcium carbonate precipitates out of solution as scale sooner than it would in the tower. Proper operation and treatment may require chemical removal of scale at least once a year. Cycles of concentration must be lower than would be permissible in a tower using the same water. A good cleaning once a month, along with proper treatment and bleed, usually results in satisfactory operation with few, if any, shutdowns due to high discharge pressure.

460 TREATMENT OF TOWER SYSTEMS

461 SYSTEMS 30 TONS AND UNDER

461.1 General

A system of this size is usually a package unit consisting of a fan unit, compressor, control system, etc. The system is direct expansion with a remote cooling tower or evaporative condenser. The only required water treatment is in the condenser water circuit. Regular cleaning of the tower, maintaining proper bleed off , and regular water treatment will prevent water problems from developing.

461.2 Scale and Corrosion

Phosphate crystals are used to inhibit the deposit of calcium carbonate scale in the tower systems and also to provide protection against corrosion.

461.3 Biological Fouling

The most common problem experienced in cooling-tower systems is the growth of green algae. If not treated, the algae spreads until the system must be shut down. Good housekeeping and chemical treatment are required to control the algae and slime found in the system. When algae is noted in the tower, the tower should be cleaned and all algae growths removed. Sodium hypochlorite, commonly referred to as laundry bleach, can be used. The bleach can be purchased at any grocery store in a 5 percent liquid solution. One pint of bleach per ten tons of refrigeration should prove effective for all towers. After 1 hour of operation, the bleed off can be reestablished. If the algae growth is excessive, the tower may have to be drained to remove the dead algae.

461.4 Disease Micro-Organisms

Some water-treatment compound suppliers would imply that their proprietary product is the only adequate control of disease micro-organisms. They reference tests conducted in conjunction with government agencies. The Center for Disease Control in Atlanta, Georgia, contends:

a. Any Environmental Protection Agency (EPA) approved biocide that uses a quaternary ammonium compound will provide the needed protection against disease micro-organisms.

b. Shock treatment, with chlorine compounds, is also effective if the pH is kept low (down to 7.0) and the residual chlorine (chlorine not attached to organism) is maintained at 2 to 3 ppm.

c. Ammonium compounds are expensive, hazardous to handle, and must be discharged to a sanitary sewer system to prevent pollution of streams and lakes. When a chlorine treatment is used, the chlorine evaporates as a gas and does not cause water pollution. Chlorine treatment is relatively inexpensive and the shock treatment is adequate.

At the present time, in the absence of formal recommendation from the Center for Disease Control or EPA and unless local conditions indicate that the present treatment is inadequate, there is no need to change cooling-tower water treatment to control disease micro-organisms.

WARNING

If a biocide containing quaternary ammonium compound is used, it must be approved by EPA and administered carefully according to suppliers' safety instructions.

461.5 Bleed Rate

The bleed rate is determined by the hardness of local water. Once the bleed is established, it should not be changed unless system conditions or water testing show that the rate is wrong. The apparent wasting of water from the bleed line is required as the small cost of the water is more than offset by the saving in electricity as a result of maintaining a scale-free system. If it is apparent that the treatment program is ineffective, contact the district and regional office.

WARNING

Never bypass or jumper automatic controls or safety devices.

462 SYSTEMS OVER 30 TONS

462.1 Contract Treatment

HBK MS-1, Operation and Maintenance of Real Property, specifies several methods of water treatment. When complete water-treatment services are contracted, use Form 4996-B, Specification for Water Treatment of AirConditioning Systems. (See Chapter 7, Specification 7-2. This specification covers all phases of water treatment required in a postal installation.) All required treating and testing equipment and all necessary chemicals should be furnished by the contractor. The type and size of the system determines the method and type of treatment. Since the specification requires the contractor to warrant the system conditions, fair and competitive bids can be obtained from all major water-treatment companies.

462.2 Continuing Existing Programs

Offices that currently run their own water-treatment programs with proven success and that would not benefit from a contract (See Chapter 7, Specification 7-2) may continue their present method, if there is no objection from the regional office.

462.3 Contracting for Full Service

.31 **Requirements.** When a contract for water treatment is being planned, all systems should be considered for inclusion in the contract. If possible, the contract should cover a two-year term with option for renewal. Either party should have the option of breaking the contract upon 30-days notice to the other party. Failure of the contractor to fulfill all contract requirements should be called to the attention of the contracting officer. (See Chapter 7, Specification 7-2, for sample specifications.)

.32 **Problems.** All problems concerning water treatment must be reported in writing to the contractor and a copy of the letter sent to the district office. A follow-up letter should be sent, within one month of the initial letter, to the district office detailing what action was taken by the contractor to remedy the problem and if the action taken is judged to be satisfactory.

463 SCALE REMOVAL

463.1 General

Scaling is a common problem that occurs in most plants where a good water-treatment program is not carried out. When scale is formed in the condenser, the heat-transfer rate between the hot refrigerant gas and the condenser water is reduced and the system capacity decreases. Condenser pressure is increased, due to the decrease in heat flow through the condenser-tube walls. As long as the scale exists in the condenser, the system will work harder and produce less cooling. As the scale increases, the system tonnage goes down and the electricity consumption goes up. The cost of water treatment is insignificant compared to the cost of maintenance when water is not treated. Scale must be removed from systems and water treatment started to prevent scale buildup.

CAUTION

Acidizing of equipment (scale removal) may only be performed by competent personnel.

463.2 Removers

.21 **General.** There are many types of acid used to remove scale. Many factors must be considered before using an acid; cost, danger (both to personnel and equipment), time, method, and ease of operation. As a means of introduction to the wide field of available acids, Table 4-3A lists the three general types of acids and the individual acid under each group used to remove material from equipment. Each of the acids is used to some extent in chemical cleaning. However, in air-conditioning systems, three of these acids, hydrochloric, sulfuric and sulfamic, are usually relied upon for removal of all types of scale or fouling. Table 4-3B lists the commercial concentration and specific gravity of three acids listed. These acids are not inhibited against metal attack.

TABLE 4-3

ACIDS

A. Classifications and Formulas

Group	Acid	Formula
Mineral	Hydrochloric (muriatic)	HCl
	Sulfuric	H_2SO_4
	Nitric	HNO_3
	Phosphoric	H_3PO_4
Dry	Sulfamic	HSO_3NH_2
	Sodium Bisulfate	$NaHSO_4$
Organic	Formic	$HCO.OH$
	Acetic	$CH_3CO.OH$
	Citric	$C_2H_8O_7 + H_2O$

B. Concentration and Gravity

Acid	Concentration %	Specific Gravity Degree Baume
Hydrochloric HCl	28-38	18-23
Sulfuric H_2SO_4	78-93	60-66
Sulfamic HSO_3NH_2	Dry Powder	Dry Powder

WARNING

Never pour water into acid--always pour the acid into water. Adding water to acid is similar to adding water to boiling oil. The hot oil causes the water to flash into steam and explosively splash out the hot oil. Dry acids such as sulfamic, used as a descaler, will burn bare skin because of skin moisture. Treat dry acids the same as liquid acids.

.22 **Hydrochloric Acid (HCl).** Hydrochloric acid is a mineral acid in a water solution containing 28 to 38 percent hydrogen chloride. Hydrogen chloride is a gas, but is easily dissolved in water. The solution is very aggressive, and effective buffers must be added to the acid solution to make it useful as a descaler.

WARNING

Proper ventilation is required when using any type of chemical or acid. Carbon dioxide gas (CO_2) is formed when acid is used to remove scale. Never inhale the fumes from any chemical or acid.

.23 **Sulfuric Acid (H_2SO_4).** Sulfuric acid is used as an alkalinity reducer. When it is the main acid used in an acid-treating system, it is easy to protect the system metal in the pH range of 6.0 to 7.5 (the range normally used in acid-treated systems). The acid costs less per pound than other acids and the cost of using H_2SO_4 in the tower water is usually recovered by the water saved as a result of increased cycles of concentration.

CAUTION

Do not use sulfuric acid (H_2SO_4) as a scale remover. This acid cannot be buffered sufficiently to make it harmless to metal when used in the low pH range.

WARNING

Heat is produced when the acid is mixed with water. Use caution and proper safety gear when working with acids. Always pour acid into water, not water into acid. When acid is used to control the pH in a cooling-tower or atmospheric-condenser system, the acid must be automatically pumped directly from an acid carboy into the system. Sulfuric acid must not be handled, mixed, or otherwise used except in approved acid carboys as received from the chemical company.

.24 **Sulfamic Acid (HSO_3NH_2).** Sulfamic acid is a dry, crystalline material, readily soluble in water to give acid solutions. The dry acid is easy to handle, mixed with solid inhibitors and surfactants, and packaged as a dry descaler. The acid solution is less aggressive than the mineral liquid acids and the cost is almost double the cost of HCl. However, this is more than offset by the increased safety, ease of transportation and ease of use. All dry acid descalers sold to remove common scale buildup are blends of sulfamic acid, inhibitors, and surfactants, plus other material added for specific uses. Ammonium bifluoride is added to sulfamic acid for removal of silica scale. These same substances are also used with HCl.

463.3 Descaling Methods

Before adding acid to the system, determine the method of removing system scale. First, determine what type and how much scale must be removed. Second, determine the type of acid to use and how much is needed. Third, determine what method to use, what effect it will have on the system, and how long it will take.

463.4 Scale Composition

.41 Determining Scale Type. With the hot end of the condenser opened, check for any scale. There are many possibilities for scale composition but, if the scale is white and powdery-looking, it is probably calcium carbonate. If it is brown and resembles a mixture of dirt and sand, it may be phosphate scale. A hard, flinty scale is probably silica scale. Sulfate scale color may vary, but it is a hard scale and easy to distinguish from a carbonate scale. Iron deposits are easy to identify. The best method for identifying scale is to take a sample of the scale material and see if it is readily dissolved in a small amount of acid solution. If gas bubbles are evident, calcium carbonate is present, and a reaction is taking place. A true sulfate scale will prove hard to remove and will be very slow to dissolve in the acid. Silica scale also shows very little reaction.

.42 Removal. Calcium carbonate accounts for over 80 percent of all scale. The thickness of the scale shows the amount of scale in the system. The more scale there is in the system, the more acid it will require to remove the scale. The following items all affect the amount of acid needed to remove scale from a system: number of gallons of water in system; temperature of water; type of scale; amount of scale; pH of water; other chemicals used in the system; cleanliness of system (other than scale); type of acid descaler; and concentration of acid in descaler.

463.5 Acid Type

.51 Dry Sulfamic. Unless a special acid is required, use the dry sulfamic acid descaler. It is safer than other acids.

.52 Solution pH. Since all descalers work their best in the lower pH range, pH is used as a control point for acid solutions. A pH of 1.5 is fairly standard for best results. This means some method is needed for checking pH. An electric pH meter is very useful, but pH test strips work as well. As the acid is used up, it must be replaced until all the scale has been consumed or has reacted with the acid.

WARNING

Explosive gases, such as hydrogen, may be produced when chemicals react with certain metals. Keep fire, sparks, etc., away from any descaling operation.

.53 Determining Solution Amount. As a general guide for carbonate scale, one gallon of HCl descaler is recommended for every 15 gallons of water and 5 pounds of sulfamic descaler for every 10 gallons of water. This is the initial charge only; additional acid is necessary to maintain the pH level. Another rule of thumb method for determining acid needs is to add 15 pounds of dry acid or 2 gallons of liquid HCl for every 10 tons of system capacity. More acid is needed for heavily scaled systems.

463.6 Acidizing Methods

.61 General. There are two methods used to acidize a system. General acidizing requires keeping the system in operation. Acid is fed into the tower sump, and the entire system is acidized. If the amount of water in the system is very large and, if necessary valves are installed, the condenser can be sealed off from the remainder of the system and acidized, thereby reducing treatment cost. This method is referred to as local acidizing.

.62 Local Acidizing. In local acidizing, the air-conditioning system must be shut down and the condenser valves closed to isolate the condenser from the rest of the system. Connections must be available in the inlet and outlet pipes to connect the rubber hoses that circulate the acid solvent. A tank or drum equipped with a small circulating pump is also required to circulate the solution through the condenser (Figure 4-1). This method of acidizing has both good and bad points, and local conditions must be taken into consideration before deciding on using it.

The advantages of local acidizing are: less acid is required, resulting in less cost; less metal is exposed to the acid; and there is no danger of foaming over and causing damage to private property.

The disadvantages are: the system must be shut down; the temperature cannot be maintained, resulting in longer time to complete the job; special equipment is needed; and acidizing produces CO_2 gas, making adequate ventilation a necessity. It is also possible that the cooling tower itself may need cleaning and this method does not provide any cleaning of the tower.

.63 General Acidizing. General acidizing uses the solution in the entire system as a cleaning solvent. The condenser-water pump is used to circulate the solution.

The advantages of general acidizing are: less trouble; the system is in operation during the acidizing; the entire system including the tower is cleaned; no extra equipment is needed; and all CO_2 gas produced is released in the tower.

The disadvantages are: the high cost (more acid required), and the danger of tower drift blowing on personnel or private property. This danger can be reduced by using an antifoam material. Some companies supply small packages of antifoam with their descalers, but the material can be purchased from any chemical company or refrigerant supply house.

The time required to acidize a system depends mainly on the amount of scale in the system, the pH of solvent, and most important, the temperature of the acid solution. Generally, acids are most effective at a temperature of 150 to 160 °F. It is not considered safe to exceed 160 °F, as the inhibitors are not effective above this temperature. Maintaining the temperature of the solution as high as possible without exceeding 160 °F increases the effectiveness of the acid and reduces the time necessary to complete the job.

WARNING

Never use acid solutions (descalers are acid) over 160 °F. Never agitate acid solutions with air.

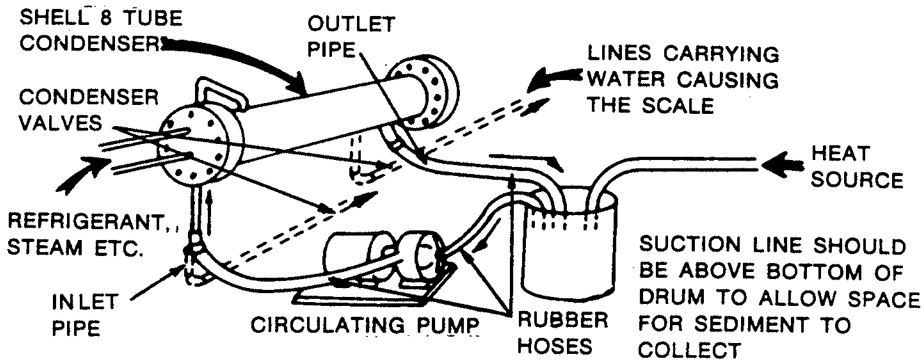


Figure 4-1
LOCAL ACIDIZING

A descaler works by ion exchange, whereby the negative acid combines with the positive scale and an ion of each is given up or cancels out another. This is similar to the action of a zeolite water softener where sodium chloride (which is negative) removes positive ions from the water (scale-forming minerals) and makes the water soft. The calcium ions are replaced with sodium ions which are not scale-forming.

Some descalers remove a pound of scale per pound of acid and others require 3 pounds of acid to remove a pound of scale. This is due mainly to the ratio of acid to other ingredients. A cheaper acid may end up costing more than a higher priced acid.

Due to an increase of negative ions, when the acid is added to the water the pH drops. As the acid reacts with scale, the negative ions are cancelled out by positive ions so the pH starts back up. As long as more acid is added, the low pH is maintained. When the scale is all dissolved, there is no further reaction, and the pH stabilizes or remains at the low level. This means that all the scale is removed.

However, the job is not finished until the system is drained, refilled, and checked to make sure that all equipment is operating satisfactorily. The pump strainer should be checked for loose material; a check should be made for piping leaks; and the float valve should be adjusted in the tower basin.

Acidizing or chemical cleaning is not complicated or difficult, if a few simple rules are applied. The following procedures can be used:

a. Gathering information. The necessary data should include: system conditions; what needs cleaning; type of scale; best method to use (local or general acidizing); gallons of water in system (as close an estimate as possible); and whether the system contains oil or grease. This information should deter-mine: if acidizing is necessary; if the system should be pretreated to remove any oil or grease in the system; what type of scale is in the system; the best acid and method to use to clean the system; and an idea of the amount of acid descaler needed.

b. Precleaning the system. If an oil film is present in the system, it can be removed by adding a low-foaming household detergent to the system. One and one-half pounds of detergent for every 100 gallons of water circulated at normal operating temperature for 15 to 20 minutes should remove all traces of oil. The tower should be cleaned before any acidizing is started. The basin should be cleaned of all loose material and as much algae as possible removed, since acidizing will kill all algae loose in the system. If local acidizing is to be used, the tower would not have to be cleaned, but it is recommended that the entire system be cleaned before the job is finished. If the system is cleaned with detergent to remove all residue, it is not necessary to drain the system to start the acidizing.

463.7 Acidizing Procedures

.71 Local Acidizing. If local acidizing is the best method, and the system is equipped with the necessary valves and connections, proceed as follows: shut down the system; shut off the condenser valves; and drain the condenser. Connect the acid hoses, drum, and pump to the condenser (Figure 4-1). Fill the drum with hot water and the recommended amount of descaler material. Circulate the solution through the condenser while checking the pH of the returning solution and adding more descaler material to maintain a pH of between 1.0 and 2.0 in the drum. (CO_2 gas bubbles from the solution indicate that carbonate material is being removed from the condenser, but the pH test is the best method to determine when the job is finished.)

.72 Heating. If the acid solution can be heated, it will speed up the descaling action and reduce the time required. It is possible to use live steam or electric heating cables to increase the temperature of the drum solution. Fire or an open flame must be kept away from the operation.

.73 Heavy Scale. For extremely heavy scale, it may be necessary to dump the solution and start over with a fresh mix, since the removed scale will slowly build up in the solution until it is saturated with solids. Before an acid solution is dumped, the pH should be allowed to rise to at least 6.0. If the pH will not rise enough or is slow in rising, any type of alkaline material, such as soda ash or caustic soda, can be used to raise the pH. This prevents corrosion of drain lines and possible polluted sewage.

.74 General Acidizing. If the general method is used, the acid descaler is added to the tower-basin intake while the system is operating. The initial charge should be added and the pH checked to determine if the pH is between 1.0 and 2.0. It may be necessary to shut off the tower fan to increase the temperature of the circulating solution. The pH level should be held by adding acid until the pH level stabilizes between 1.0 and 2.0 without additional feed. The pH then should be raised to 6.0 and the system drained. The tower basin should be checked for material and flushed out if necessary. If the system is to be put back into operation, it is not necessary to flush the system. If the system is to be laid up, it should be filled, the pH checked to make sure it is above 7.0, and the water allowed to circulate for 30 minutes before the system is shut down and drained for layup.

463.8 Safety Requirements

Always follow these procedures:

a. If liquid descaler is used, make sure 1-gallon, unbreakable plastic containers are specified.

b. If dry-powder acid is used, keep completely dry until mixed for use.

c. Use and wear safety gear. Rubber aprons, gloves, and goggles are a must.

d. Pour acid into water; never pour water into acid.

e. Do not permit acid to contact bare skin or eyes.

f. Keep all fire, sparks, etc., away from descaling operation.

g. Keep solution from concrete floors or other material that might be damaged.

h. Explosive gases may be produced, depending upon reaction of acid on different metals in system.

i. Make sure proper ventilation is supplied. When using local acidizing, special care is necessary to prevent accumulation of CO_2 gas.

j. Always fill closed units from the bottom up.

k. Do not acidize systems known to have leaks.

l. When using a pump for local methods, make sure the pump is checked for proper ground and all wiring is safe.

m. Check drum and pump before using. Acid will slowly destroy both.

n. Do not agitate acid solutions with air.

o. Never acidize systems with aluminum parts.

p. If tower is galvanized steel, use local method if possible.

q. Do not dump strong acid solutions in sewer or drain on ground.

r. Use antifoam if necessary and prevent foam or tower drift from blowing on personnel, cars, etc.

s. Dispose of used acid solutions. Never store acid in metal containers.

t. Never use acid solutions over 160 ^{o}F.

u. Keep unauthorized persons away from descaling operation.

v. Make one person responsible for entire operation and do not leave equipment until the operation is finished.

w. Complete all acidizing operations the same day. Do not leave acid in system unless responsible person is present.

x. Keep constant watch for plugged pump strainer or blocked lines during operation.

y. Use good common sense at all times.

NOTE

This is not a complete list of safety regulations. Good common sense plus the required technical knowledge go hand-in-hand to produce and maintain a safe work environment.

470 GLYCOL ANTIFREEZE IN CHILLED-WATER SYSTEMS

471 GENERAL

The toxicity of glycol solutions requires that any system using glycol be isolated from potable-water systems. The system using glycol must not have any cross-connection between it and the potable-water system that is not in accordance with local codes. If the systems are cross-connected, there are two acceptable methods of repair; removing the connecting piping or installing a reduced-pressure zone-type backflow preventer between the systems. Check valves are not suitable for this application.

472 INHIBITORS

Ethylene glycol is corrosive and requires the use of inhibitors and buffers. The inhibitors normally used with glycol exhaust themselves, due to contact with oxygen and heat. Periodic tests should be run to ensure proper levels of inhibiter. Galvanized surfaces in particular are prone to attack by glycol solutions. Glycol should not be used with such types of water treatment as oxidants. The water-treatment chemical manufacturer should be consulted about compatibility before using glycol in the chilled-water system.

473 USE

Using ethylene glycol in a chilled-water system results in decreased system efficiency and capacity. This decrease in efficiency and capacity is a result of changes in the viscosity and specific heat of the mixed water and glycol. Increasing the percentage of glycol in the solution increases the problem. If glycol is used, it should be mixed in the lowest percentage that offers adequate freeze protection to minimize the reduction in efficiency and capacity.

474 ACTUAL TONS

474.1 General

When figuring actual tons of refrigeration on Form 4994, Operating Log for Centrifugal Refrigeration Plants, two corrections must be made in the formula.

474.2 Evaporator Flow

The chilled-water flow reading in gallons per minute (gpm) requires correction due to the increase in viscosity of the solution. The manufacturer of the flow meter used in the system should be consulted for flow-correction factors. This factor must then be used when figuring evaporator flow in gpm.

474.3 Specific Gravity and Heat

The changes in specific gravity and heat of the solution also require correction. Exhibit 4-1 is used to find the correction factor when the specific gravity of ethylene-glycol solution in the system is known. When the percentage of ethylene glycol in the solution is known, use Exhibit 4-2 to determine the correction factor. (The factor is always less than one.) The following formula is then used:

$$\text{Tons} = \frac{\text{gpm} \times \text{TD}}{24} \times \text{Correction Factor}$$

NOTE

Where gpm is corrected flow rate in gallons per minute, TD is temperature difference in ^{o}F.

480 WATER TESTING

481 GENERAL

It is possible to have a poor water-treatment program while using the best treatment, treating equipment, methods, and intentions. All treatments are intended to accomplish a certain purpose when used in a set manner and when maintained at a predetermined level.

482 CONTROLS

Due to constantly changing conditions, it is necessary to keep strict control on chemical levels and to recognize danger signs in water analysis reports. Water testing is used here to describe the required tests made locally to maintain set limits on conditions or chemicals. Water analysis is used to describe a series of tests made to show the entire water makeup.

483 WATER TESTS

To maintain a good water-treatment program, make water tests often enough to maintain control of water conditions. On a once-through water system, where the water is in the system for a total of perhaps 5 minutes, a monthly test would show what the condition of the water was at the time the sample was taken, but it would not show what occurred between tests. If any phase of the treatment is critical, it must be checked often enough to ensure that treatment levels are being maintained.

484 CITY-WATER ANALYSIS

484.1 General

Although the system may be in perfect operating condition, a city-water analysis report is very important and has a direct effect on the treatment of the cooling-water system where city water is used as makeup water.

484.2 Analysis

All water-treatment programs and cycles of concentration maintained are determined by an analysis of the makeup water. In order to determine what is taking place in the system water, it is necessary to know what the system started with and what is being used as makeup. Cycles of concentration are based on the makeup water, and all treating chemicals and treatment levels are determined by the makeup analysis. Where city water is used, a complete water analysis can be obtained by calling the local water department.

484.3 Analysis Results

Water analysis results are stated in parts-per-million (ppm). One part-permillion means one part in a million parts. Since ppm, as defined in watertreatment work, is a measure of proportion by weight and is equal to a unit weight per million unit weights of solution, the units (pounds, gallons, etc.) must be defined to know what is being compared. Hardness or total hardness is listed in ppm and expressed as $CaCO_3$ or calcium carbonate.

485 WATER TESTING FOR CONTROL

Although a complete water analysis is very important in water treatment, there is no need to make unnecessary tests when checking chemical levels in the system. If it is necessary to operate a zeolite water softener by hand, based on water tests, the hardness of the outlet water would have to be known to determine when to recharge the unit, and the chloride content of the rinse water would have to be known to determine when to end the rinse cycle. Other tests would be of no value. Control tests are made to determine that a certain level of treatment or condition exists, and if the treatment should be altered to stay within the control range. Control testing should be backed up by frequent complete analysis to ensure that all conditions are satisfactory and to verify the control check accuracy. When a water-treatment program is determined for a particular plant, a control range for each condition is also determined and it then becomes the responsibility of Plant Maintenance to maintain the condition in the system within the approved or recommended level.

486 TESTING METHODS

486.1 Acceptable Methods

There are many types and methods of testing water. A chemical laboratory uses equipment that gives very accurate results, but this accuracy is not necessary in the field for control purposes. Control tests should be conducted with equipment that is easy to use. The tests should require little time to conduct and should give fairly accurate results when used by persons with no formal chemical training. Titration and colorimetric are the most common types of testing used in the field, although some offices make use of electric pH meters and conductance meters when the testing is required to be accurate or is required frequently. Titration is the process of adding a standard solution to a prepared sample until a color change or endpoint is reached. The amount of standard solution used determines the ppm of the desired test. Colorimetric analysis is a procedure where a measured sample is prepared and matched to a color standard. The easiest test kit to use is referred to as a drop-test kit. The standard solution is added one drop at a time from a small plastic bottle and the drops are counted until the endpoint is reached. Some drop-test kits give results in grains per gallon (gpg). This reading can be changed to ppm by multiplying by 17.1. Testing requirements are determined by the type of system, treatment used, makeup water, and degree of control necessary to obtain the proper results. Drop-test kits should be used at all offices where it is necessary to control system water by adjusting chemical treatment.

486.2 Unacceptable Methods

There are a number of firms promoting nonchemical devices to replace conventional chemical water-treatment approaches. These devices are claimed to function by electronic, electrostatic, magnetic, ultrasonic, and other physical principles. The Bureau of Mines Industrial Water Laboratory has furnished information showing that these devices do not work and that the scientific principles referenced are not applicable to HVAC water conditioning. These devices are not to be used in postal facilities.

490 CONTRACTING FOR WATER TREATMENT

When water-treatment services are contracted, use Form 4996-B, Specifications for Water Treatment of Air Conditioning Systems. Instructions for contracting are in Chapter 7.

NOTE

For additional information on basics, theory, and practice of industrial water treating, the following publications are recommended:

System Handbook, American Society of Heating, Refrigerating and Air-Conditioning Engineers

Beta Handbook of Industrial Water Conditioning

Cooling Water by Nalco Chemical Co.

Mogul Water Treatment Program by Mogul Corporation

Practical Boiler Water Treatment Including Air-Conditioning Systems by Leo I. Pincus

Water Treatment for HVAC and Potable Water Systems by Richard T. Blake

491 WATER TREATMENT GLOSSARY

aggressive water. Soft water with less than 60 ppm of magnesium and calcium salts. This water will readily hold various compounds in solution.

algae. A minute form of plant life requiring light and water for growth and requiring control by one of the common algaecides.

algaecide. Chemicals that are introduced into the system to control algae growth. Some of these chemicals are chlorine, copper sulfate, permanganates, phenolics, or commercial combinations thereof.

alkalinity. The sum of the carbonate, bicarbonate, and hydrate ions in water determines alkalinity. Other ions such as phosphate or silicate may also contribute partially to alkalinity. Alkalinity is normally expressed as ppm of $CaCO_3$ (calcium carbonate).

bacteria. The smallest living organisms found in water. They are capable of consuming iron, lumber, and all organic matter.

bleed off. The ejection or draining of a portion of the concentrated water from a circulating water system which is replaced with makeup water. This results in reducing the cycles of concentration. Bleed off may be continuous and adjusted by a hand valve or it may be automatically controlled.

blowdown (or bottom blow). This refers to the practice of draining water from the bottom of the boiler to reduce boiler water concentration and sludge. Blowdown is done only as needed and the need should be determined by the person who is responsible for water treatment, through analysis of the boiler water.

closed recirculating system. A system in which water flows in a repetitive or continuous circuit. The system is not open to the air. In a closed system, no evaporation should take place nor should makeup be required.

coagulation. The clumping together of solids to make them settle out of the water more rapidly. Chemicals such as lime, alum, and polyelectrolytes are used to cause coagulation.

corrosion. Destruction of a metal by chemical or electrochemical reaction with its environment. The corrosion products may be soluble or insoluble and may be deposited close by or may be carried along and deposited anywhere in the system.

cavitation erosion. Loss of metal or material associated with the formation and collapse of cavities in the liquid at a solid-liquid interface.

chlorides. Chlorides of calcium, magnesium, sodium, iron, and other metals are salts normally found in water. These salts are extremely soluble.

cycles of concentration. The ratio of dissolved solids of one particular mineral in recirculating water to the solids or minerals in the makeup water. Chlorides are normally used.

dissolved solids. Solids which are in true solution in water and which cannot be filtered out.

effluent. The liquid that comes out of a treatment system after completion of the treatment process.

erosion. Removal of metal or material by the abrasive action of liquid or gas, accelerated by the presence of solid particles in suspension.

film. A thin, not necessarily visible, layer of material.

flocculation. The process by which certain chemicals form "floc" or clumps of solids which settle out of the liquid.

fretting corrosion. Surface corrosion between two contacting surfaces that are subject to a slight movement or vibration.

fouling. Accumulation of solid materials, other than scale, in such a manner that it affects operation.

galvanic corrosion. Generally results from the presence of two dissimilar metals in an electrolyte. Characterized by an electron movement from the metal of high potential (anode) to the metal of lower potential (cathode), resulting in corrosion of the anodic metal.

galvanic series. A list of metals and alloys arranged according to their relative potential in a given environment.

hardness. Primarily the sum of calcium and magnesium salts in water although it may include other elements, mainly aluminum, iron, manganese, strontium, or zinc. Temporary or carbonate hardness is that portion of total hardness which can combine with the carbonate (CO_3) or bicarbonate (HCO_3) ions. The balance of the hardness is called noncarbonate or permanent hardness. This is principally caused by sulfates, chlorides, and/or nitrates of calcium, and/or magnesium.

impingement attack. Corrosion associated with turbulent flow of a liquid. Unusually accelerated by entrained bubbles in the liquid.

inhibitor. A chemical substance or mixture which, when added (usually in small concentration) to a solution, effectively reduces scale or corrosion or both.

microbe. A minute living thing, either plant or animal.

mill scale. The heavy oxide layer formed during hot fabrication or heat treatment of metals.

makeup water. The water from a normal supply which is added to compensate for evaporation, windage, leaks, blowdown, and other water losses.

open recirculating system. A system through which water flows in a repetitive circuit through heat exchangers and reservoirs open to the atmosphere, such as cooling towers or air washers. **oxidation.** A chemical reaction that takes place on the surface of a metal due to a loss of electrons from a part of the metal.

ppm (parts per million). A method for expressing unit concentrations of a chemical in water analysis. One part per million means that one unit weight of a chemical is contained in one million of the same units of water; for example, one ounce of chemical in one million ounces of water.

pH. Denotes the degree of acidity or alkalinity of a solution. A value of 7 is neutral; values below 7.0 are increasingly acid; values above 7.0 are increasingly alkaline.

pollution. Results when something--animal, vegetable, or mineral--reaches water, making it more difficult or dangerous to use for drinking, recreation, agriculture, industry, or wildlife.

raw water. Water that has received no special treatment for system use. It may be pure for drinking and other domestic use, but may or may not require special treatment before it can be used, such as raw water for high-pressure boiler makeup.

scale. A deposit formed from solution directly upon a confining surface. It is usually crystalline and dense, frequently laminated and occasionally columnar in structure, and usually the result of super-saturated water constituents.

slime. A gelatinous mass of bacteria and micro-organisms which in general are found with dirt, debris, algae, fungi, and salts.

sludge. A water-formed sedimentary deposit. It may be hard and adherent, and baked to the surface upon which it is deposited. Treatment is used to maintain sludge in a soft, nonadherent state.

suspended solids. Solids which are in suspension and can be removed from the water by filtration.

treatment. Any material, chemical, or process used with the makeup or system water to produce some type of action or result that controls corrosion or scaling in any manner. There are two basic methods of treatment: (1) External treatment where the makeup water is treated before it is added to the system, and (2) Internal treatment where chemicals are added to the system water.

CHAPTER 5

HEATING

510 GENERAL

511 SCOPE

This chapter covers the recommended procedures for the safe, economical operation and maintenance of automatically fired boilers. It is not intended to serve as operating instructions for any specific heating plant. Due to the wide variety of types and makes of equipment used, this chapter should be supplemented with the manufacturers' recommendations concerning maintenance and care and specific written operating instructions for each system.

512 INSPECTION OF NEW BOILERS

Before any new heating plant (or boiler) is accepted for operation, a final (or acceptance) inspection must be completed and all items of exception must be corrected. In addition to determining that all equipment called for is furnished and installed in accordance with the plans, specifications, and applicable codes, all controls must be tested by a person familiar with the control system.

513 SAFETY

513.1 General Guidelines

Safety is very important in boiler operation and should be foremost in the minds of those who operate and maintain heating systems. Only properly trained, qualified personnel may work on or operate mechanical equipment. Adequate supervision must be provided.

513.2 Lighting

The boiler room must be well lighted and equipped with an emergency light source in case of power failure. If a flashlight is used for this purpose, it must be maintained in working order and protected against removal from the boiler room.

513.3 Ventilation

The boiler room must have an adequate air supply that permits clean, safe combustion and minimizes soot formation. An unobstructed air opening must be provided. It may be sized on the basis of 1 square inch free area per 2,000-Btu maximum-fuel input of the combined burners located in the boiler room, or as specified for the particular job conditions in the National Fire Protection Association (NFPA) standards for oil-and gas-burning installations. The boiler room air supply openings must be kept clear at all times.

513.4 Fire Protection

Fire-protection apparatus and fire-prevention procedures for boiler room areas should conform to recommendations of the NFPA.

514 WATER AND DRAIN CONNECTIONS

514.1 Water Connections

Proper and convenient water-fill connections must be installed. Provisions should be made to prevent boiler water from backfeeding into the service-water supply. A convenient water supply that can be used to flush out the boiler and to clean the boiler room floor should be provided in every boiler room.

514.2 Drain Connections

Proper and convenient drain connections should be provided for draining boilers. Unobstructed floor drains properly located in the boiler room will make proper cleaning of the boiler room easier. Floor drains that are used infrequently should have water poured into them periodically to prevent the entrance of sewer gases and odors. If there is a possibility of freezing, an antifreeze mixture should be used in the drain traps.

515 HOUSEKEEPING

Generally, a neat boiler room indicates a well-run plant. The boiler room should be kept free of all material and equipment not necessary to the operation of the heating system. Good housekeeping should be encouraged, and procedures should include routine inspections to maintain the desired level of cleanliness.

516 POSTING OF CERTIFICATES AND/OR LICENSES

Some states and municipalities require licensing or certification of all personnel who operate or maintain heating equipment. Some authorities also require the posting of inspection certificates in the boiler room. The supervisor in charge of a given installation must ensure that such requirements are met. However, it should be noted that, as a Federal agency, the USPS is <u>not</u> required to comply with all local codes and/or licensing requirements.

517 RECORDKEEPING AND LOGS

517.1 Schematics, Diagrams, and Instructions

All drawings, wiring diagrams, schematic arrangements, manufacturers' descriptive literature and spare parts lists, and written operating instructions should be kept permanently in the boiler room or other suitable location so they are available to those who operate and maintain the boiler. Where space permits, drawings and diagrams should be framed or sealed in plastic and hung adjacent to the related equipment. Other material should be assembled and enclosed in a suitable binder. When changes or additions are made, the data and drawings should be revised accordingly.

517.2 Log Book

A permanent log book should be provided in each boiler room to record maintenance work, inspections, certain tests, and other pertinent data. Brief details of repairs or other work done on a boiler plant (including time started, time completed, and signature of person in charge) should be recorded. Performance and results of tests, inspections, or other routines required by codes or laws, insurance company inspection reports, and initial acceptance test data should be recorded. A suggested sample of a boiler room log is shown in Exhibits 5-1 and 5-2.

517.3 Maintenance Schedules and Records

A suggested chart-type log for scheduling and recording maintenance work, testing, and inspection performed during any one period is shown in Exhibit 5-3. The routine work normally performed on heating boilers is listed. As each portion of the work is completed, the initials initials of the person performing the work and the date should be entered the in the appropriate space. A master maintenance checklist is provided in Exhibit 5-4, Appendix C.

518 FUELS

518.1 General

Gas, oil, coal, or wood products are the principal fuels used in boilers. Electricity serves as a source of heat.

518.2 Coal

.21 **Use.** Generally, coal is not used as a fuel in postal intallations. Coal usage is not covered in this handbook because, although automatic equipment for burning coal is not commonly used, a brief treatment of coal is considered to be in order.

.22 **Anthracite and Semianthracite Coal.** Anthracite coal is dense and stonelike in structure and shiny black in color. Because of its hardness, it can be handled with little breakage. When ignited, it burns freely with a short, relatively smokeless flame, and does not coke (create a residue). It has very little volatile matter and is commonly referred to as hard coal. Semianthracite is not as hard as anthracite and is higher in volatile matter. It is dark gray in color and of a granular structure. Semianthracite swells considerably in size when burning, but it does not coke. The "as received" heating value of anthracite and semianthracite coals, is 12,000 to 13,000 Btu/lb.

.23 **Bituminous Coal.** This classification covers a wide range of coals, from the high grades found in the Eastern United States to the lower grades of the West. Bituminous coal, commonly called soft coal, is the most extensively used of all coal. The various types of soft coal differ in composition, properties, and burning characteristics. Some are firm in structure and present no handling problem; others tend to break when handled. Bituminous coals ignite easily and burn readily, usually with a long flame. Medium-volatile and high-volatile coals coke in the fire and smoke when improperly burned. The "as received" heating values of bituminous coals vary from approximately 10,500 to 14,500 Btu/lb.

518.3 Gas

.31 **Heating Values.** Gas used for fuel comes in the form of natural, manufactured, mixed, or liquefied petroleum gas. Natural, manufactured, and mixed gases are normally distributed through underground piping, and require no storage facilities. Heating values of these gases in Btu per cubic feet are:

	Low	High
Natural Gas	950	1150
Manufactured Gas	350	600
Mixed Gas	600	800

.32 **Natural Gas.** Natural gas is an excellent boiler fuel and requires only simple equipment for burning. Most suppliers now add a chemical to the gas which results in an objectionable odor so that leaking gas will be noticed before the concentration of gas becomes dangerous. The composition of the gas varies according to the source. However, methane is always the major part and usually is combined with ethane and nitrogen.

.33 **Standard Heating Value.** Gas suppliers have a standard heating value which they agree to maintain. Although most maintain a 1,000-Btu/ cu ft rating, the local gas office should be contacted if the exact rating is unknown. When the Btu rat ing is available, a simple time check using a stopwatch and the meter reading while the boiler is operating at full load will determine the number of cubic feet per minute (cfm) of gas used in the boiler. This is the method used to check Btu input of a burner, and the local gas company will usually provide assistance in making this test.

.34 Efficiency Tests. A flue-gas analysis requires special equipment and tests samples of the flue gases leaving the boiler. Results of a good test would show no carbon monoxide present, 5 to 10 percent excess air, and a carbon dioxide reading between 7 and 11 percent at a stack temperature between 400 and 500 °F. By using the above readings, a fuel-efficiency table should show an efficiency rating of 78 to 82 percent. This means that for each cubic foot of gas used in the burner, 78 to 82 percent of the heat content is absorbed into the boiler. The remaining heat content is lost by incomplete combustion, by heating of the air required for combustion, and heat going up the stack. Output of individual boilers and burners may vary somewhat from these figures; the manufacturer's operator's manual should be used to determine the exact figures pertaining to a certain burner or boiler.

.35 Liquefied Petroleum Gas (LPG). Liquefied petroleum gas is normally stored in tanks at high pressure so that it will remain in a liquid state. Storage may be either above or below ground; storage and handling requirements should be in accordance with NFPA Pamphlet #58 and local regulations. (To obtain Pamphlet #58, write to National Fire Protection Association; Batterymarch Park; Quincy, MA 02269-9101; ATTN: Publications--Sales Division.) The liquefied fuel is reduced in pressure and its state is changed to a gas at the required pressure for the burner. Propane or butane gas has a heating value of 2,500 to 3,300 Btu/cu ft. Modification of the fuel-burning equipment is necessary when changing from liquefied petroleum gas to other gases or from other gases to liqueifed petroleum gas.

518.4 Fuel Oils

.41 Classification. Fuel oils are graded in accordance with the specifications of the American Society for Testing Materials. Oils are classified by their viscosities. Other characteristics of fuel oils that determine their grade, classification, and suitability for use are: the flash point, pour point, water and sediment content, sulphur content, ash, and distillation characteristics. Fuel oils are prepared for combustion in most lowpressure boiler burners by atomization (spraying). Types of atomization commonly used are: high-pressure mechanical atomization, low-pressure mechanical atomization, centrifugal atomization (rotary cup), compressed-air atomization, and steam atomization.

.42 Use. Fuel oil may be the only fuel used in a boiler or, where natural gas is the primary fuel, fuel oil may be used as a standby fuel. In some sections of the country where the natural gas supply is critical or subject to interruption, large users of gas are required to maintain a standby fuel so gas service can be interrupted without loss of heating capabilities. Fuel oil is procured from local suppliers and stored on-site in storage tanks for use as needed. Most plants cannot store a normal year's supply of fuel and, where experience has shown a fuel oil shortage to be possible, fuel oil usage must be anticipated and storage tanks refilled so that an adequate supply is available during a heavy usage period.

.43 Specifications. Fuel oil specifications must show the Btu heating value, specific gravity, sulphur content, viscosity, and allowable sediment, so that all oil purchased is consistent in quality and usage. Oil burners are designed and adjusted to fire with certain grades of oil; care must be exercised to ensure that all fuel oil used meets a particular air requirement. Air adjustments may be necessary every time a change is made from one oil tank, or type of oil to another. A flue-gas analysis should reveal a carbon dioxide reading of 8 to 13 percent without smoke or carbon monoxide. A range of 10 to 13 percent is normal for most burners. Excess air should range from 3 to 15 percent, and the stack-gas temperature should be between 400 and 650 °F. Efficiency figured by a combustion slide chart will normally range from 80 to 82 percent. A stack-gas temperature less than 380 °F above room temperature may cause the moisture in the stack gases to condense and cause what resembles fly ash to leave the stack. Any sulphur in the fuel combines with the moisture to form sulphuric acid, causing corrosion of the stack and breeching. Outside air inlets for combustion air should provide at least one square inch of inlet area open space for each gallon of fuel used per hour. Smoke level should not exceed No. 1 when checked by the conventional spot-type smoke tester.

.44 Fuel Oil Grades. Fuel oil grades are as follows:

a. Grade Number 1. A light-viscosity distillate oil intended for vaporizing pot-type burners. The heating value is approximately 135,000 Btu/gal.

b. Grade Number 2. A distillate oil used for general purpose heating. This oil grade is most commonly used in low-pressure boiler oil burners. It does not require preheating before burning and is easy to ignite and control. Almost all boilers with burners which use oil as a standby fuel use No. 2 oil because it is easy to store and use. Specifications for No. 2 fuel oil are as follows: 7.0 to 7.3 pounds per gallon; 137,000 to 141,800 Btu heating value per gallon; and 30 to 38 °F specific gravity as per American Petroleum Institute (API). The oil grade alone does guarantee a certain quality. The average heating value for No. 2 oil is 138,000 Btu/gal (see Table 5-1).

c. Grade Number 4. This is heavier than No. 2, but not heavy enough to require preheating facilities. Because the oil is no longer available in many locations as a straight-run distillate, and is a mix of No. 2 and heavier oils, it may be necessary in Northern states to provide tank heaters or small recirculating preheaters to ensure delivery of the blended fuel to the burner. If the fuel is not blended properly, the No. 2 oil and the heavier oil may separate eventually. Many dealers blend the two grades of oil in the tank truck while delivering the oil to the location. This may result in the physical separation of the two grades if they stand in the tank for any length of time. The heating value of grade 4 is approximately 147,000 Btu/gal. API gravity ranges from 20 to 28 and its weight varies from 7.4 to 7.8 pounds per gallon.

d. Grade Number 5. This grade has been divided into <u>hot</u> No. 5 and <u>cold</u> No. 5. The hot grade requires preheating; the cold may be burned, as is, from the tank but because of the increased demand for distillate products, the residual oils may be lower in quality and may require necessary preheating for good results. Sometimes Grade No. 5 is a mix of Grade No. 2 and Grade No. 6. The usual heating value is approximately 152,000 Btu/gal.

e. Grade Number 6. This is the heaviest grade of fuel oil and is commonly referred to as "Bunker C" oil. The Btu/per gallon is the highest of the five common fuel oils and the cost is the lowest. Due to the weight and consistency of the oil, it must be heated before it can be burned. If stored outside, the storage tanks must have heaters to maintain a high enough oil temperature to allow the oil to be pumped. Air pollution is another problem associated with using No. 6 oil but, since it is more plentiful than the higher grades of fuel oil, it may become necessary to convert some boilers to

TABLE 5-1

GRAVITY AND HEATING VALUE OF FUEL OILS

GRADE NO.	GRAVITY API	WEIGHT, LB. PER GALLON	HEATING VALUE BTU PER GALLON
1	38 - 45	6.675 - 6.95	132,900 - 137,000
2	30 - 38	6.690 - 7.29	137,000 - 141,800
4	20 - 28	7.396 - 7.78	143,100 - 148,100
5	17 - 22	7.686 - 7.94	146,800 - 150,000
6	8 - 15	8.053 - 8.44	151,300 - 155,900

burn No. 6 fuel oil. The usual heating value is approximately 153,000 Btu/gal.

.45 Preheating Requirements. The correct temperature range must be used for each grade of preheated oil. Improper preheating causes poor combustion, smoke, and high fuel consumption. The oil delivered to the burner must be preheated to the temperature recommended by the burner manufacturer for the grade of fuel used.

518.5 Electricity

Although electricity is not a fuel, it is used as a source of heat for heating boilers. The two general methods of application are electrodes and immersed direct-resistance elements. When electrodes are used, the boiler water serves as the heating element by offering resistance to the passage of current between the immersed electrodes. Direct-resistance elements create heat by the resistance offered to the passage of electric current through the immersed element.

518.6 Combination Fuels

In all cases where natural gas is the primary fuel and a secondary fuel is required, fuel oil is used as the standby fuel. Generally, No. 2 oil is specified as the standby fuel. A reduced gas rate is usually obtainable when a secondary or standby fuel is required.

519 COMBUSTION

519.1 How Fuels Burn

In boilers, burning or combustion is a form of oxidation (the union of a substance with oxygen). Oxygen combines rapidly with a fuel and releases heat. To produce combustion, in addition to the fuel and oxygen, some type of flame or heat is needed to vaporize part of the fuel and start the burning process. Under certain conditions, combustion may be self-starting. All fuels must be changed into a gas before they will burn. To do this, the surface temperature must be raised to a point where some of the fuel will vaporize or become a gas. Some fuels such as gasoline, propane, etc., vaporize at a low temperature and are extremely easy to ignite. Others, such as coal and wood logs, require much higher temperatures before they will vaporize enough to ignite.

519.2 Gas Combustion

Since all fuels burn as gases, combustion mixtures must be considered. Before vaporized gases from the fuel will burn, they must be mixed with air. The temperature of the mixture then must be raised to the ignition point and held there while combustion takes place. The gas/air mixture is very important and is one of the items controlled by the operator. In all fuels, the two basic elements are hydrogen and carbon. Other elements such as sulphur may be present and give off heat, but these are considered impurities.

519.3 Air Requirements

The amounts of hydrogen and carbon that appear in any fuel are very important to burning, and the proper amount of oxygen must be supplied to each type of fuel to have complete combustion. By computing a fuel/air ratio, it is easy to determine exactly how much air is needed for perfect combustion of any type of fuel. The ratio is usually expressed in terms of weight and simply means that for a unit weight of a certain type of fuel, a certain weight of air is required for combustion. The fuel and air must be mixed in the proper proportion for complete combustion to take place.

519.4 Ignition Temperature

In addition to fuel and air, a third factor--heat--is required for combustion. If heat is added gradually, a point will be reached where the fuel is producing enough heat to maintain its own combustion. This is called the ignition temperature; from this point on, no external heat is needed to produce combustion. Below this point, the fuel will not burn freely and continuously unless some form of heat is supplied to it. Actual ignition temperature is affected by surrounding conditions. For each type of gas, a certain amount of air is required; poor combustion will result if the fuel/air mixture is too lean or too rich. The range between the two limits is known as the "limits of flammability."

519.5 Proper Mixing

In a boiler, the mixing of fuel and air is a complicated process. The separate streams of fuel and air entering the boiler must be accurately mixed and heated to start and maintain combustion. The manner in which this is accomplished is one of the main factors in boiler and burner design and may be the determining factor in whether or not a boiler is effective and economical.

519.6 Incomplete Combustion

Incomplete combustion is the unfinished burning of fuel that leaves parts of it in some state of chemical decomposition other than carbon dioxide, the end product of complete combustion. When fuel is burned without sufficient oxygen, carbon particles in the form of smoke or soot are produced as is carbon monoxide (CO), a lethal gas. Incomplete combustion results in higher fuel costs; the carbon deposits reduce heat transfer through the boiler tubes, which increases the overall operating and maintenance costs. See Exhibit 5-5 for examples of the effect of soot on fuel consumption.

519.7 Excess Air

Excess air ensures complete combustion, but also presents problems and causes a loss of efficiency. Since the excess air must be heated along with the air used for combustion, the boiler is robbed of heat which would have been transferred to the boiler water. Every 10 percent in excess air results in a loss of 1 percent of the total fuel used. Excess air also causes or promotes corrosion in a boiler using fuel oil or coal as a fuel. Most boiler manufacturers specify required air supply at full-rated load and these specifications should be followed; however, the best check is to ensure that the flue gas contains a small amount of excess oxygen. The lower this excess can be maintained, the more efficient the boiler will be. The only danger is in burner modulation, where the ratio of fuel to air may not be controlled and the possibility of insufficient air could be encountered. If natural gas is used as the fuel, the local gas company will sometimes perform flue-gas analysis without charge. It is standard practice to set air requirements for natural gas burners at approximately 25 percent over the required amount. Regardless of the amount of air going through a boiler, incomplete combustion will result unless the air is adequately mixed with the fuel. Most burners have primary air that is mixed directly with the fuel and secondary air which enters the combustion chamber to supply the air needed to complete the process of combustion. Aa certain amount of time is required for fuel to burn completely; this takes place while the fuel and air mixture is traveling through the combustion chamber or firebox. If air leaks are not repaired or boiler doors are left open or do not close tightly, air will enter the boiler but will not be usable for the required air/fuel mixture.

520 CENTRAL HEATING SYSTEMS

521 STEAM SYSTEMS

521.1 General

Some buildings are heated by steam radiators, air handlers with steam-heating coils, or a combination of both. The most common steam radiator systems are the one-pipe, condensate-return, and combination systems.

521.2 One-Pipe System

In a one-pipe system, the boiler operates with a steam pressure of 1 to 3 psig and is connected to the radiators by a single pipe 1-1/2 to 3 inches in diameter. The pipe must be slightly sloped so that all condensate returns directly to the boiler or to a condensate-return tank where the condensate is pumped back into the boiler. The steam and condensate travel in opposite directions in the same pipe. Each radiator and riser pipe is equipped with an air-vent valve. When there is no steam pressure on the system, the supply lines and the radiators are filled with air. One of the problems encountered with the one-pipe system is its inherent tendency to store water in the radiators and cause the boiler to shut down because of low water. This problem is increased when the radiators are controlled manually. The supply line must be either wide open or closed. When it is partially closed, the steam pressure will not allow the condensate to leave the radiator. The radiator fills up with water until it is forced out through the air-vent valve. Boilers used with one-pipe heating systems should not be equipped with automatic makeup valves to maintain boiler water level. Makeup water should be added by hand when necessary. A low-water cutoff device is essential and must be checked weekly for proper operation.

521.3 Condensate Return System

.31 Operation. Steam boilers depend on steam condensate-return systems to maintain the boiler water level. Untreated raw water is used to replace any lost steam or condensate. Low-pressure, steam-heating boilers should operate with over 85 percent of condensate return. Some boiler water is lost by blowing down external attachments such as the water column, water-level controller, and low-water fuel cutoff. Total water loss from the system is minor if the return system is maintained in top condition and all condensate is returned to the boiler.

.32 Types. The condensate-return system may be a vacuum system that maintains a vacuum on the entire return system up to the individual steam traps, or it may be a gravity-return system, where the condensate drains into an atmospheric-type return tank. A steam trap is required in the outlet from each radiator. Supply lines and headers are equipped with traps to prevent condensate returning through the steam outlet to the boiler. In systems with condensate-return tanks, the condensate is pumped back into the boiler each time the level rises high enough in the tank to trip a float switch. Makeup water may be added to the boiler itself, or it may be added at the condensate-return tank. The condensate may be pumped back into the boiler as it returns from the system, or it may be pumped into the boiler when the boiler water level controller signals that the water level is low. Regardless of the type of return system, it is important to determine that no water or steam is being needlessly lost from the system and the condensate-return system is functioning as designed.

521.4 Combination System

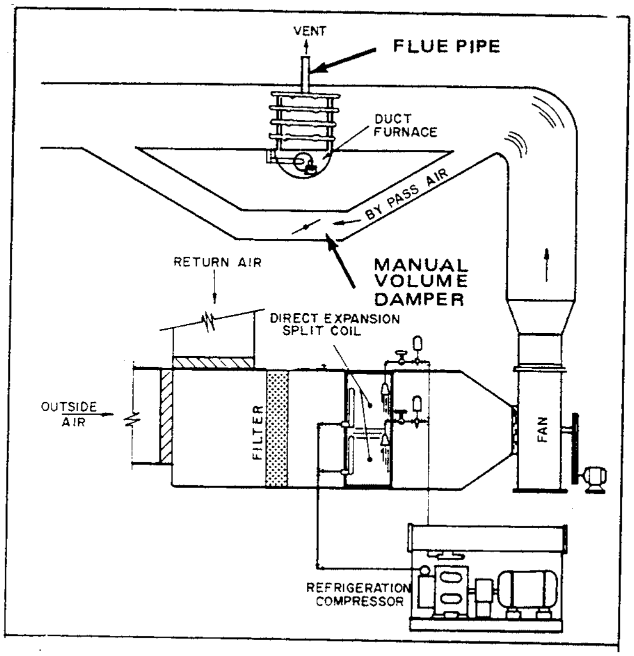
When a radiator or convector system is used in conjunction with air handlers, separate controls are used to regulate the two systems. The air handlers are designed to maintain room temperature until it is cold enough outside to require additional heat from the wall units located on outside walls. The wall units are intended to offset heat loss through the walls only, not to heat the room. However, the two systems will fight for control if thermostats controlling radiators or convectors are not set lower than thermostats controlling discharge air temperature from air handlers. A higher setting causes overheating and loss of both efficiency and comfort.

522 HOT-WATER SYSTEMS

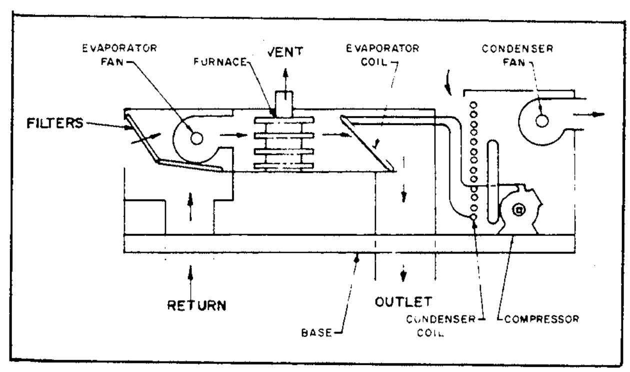
New facilities generally use low-temperature, hot-water systems. These systems are designed to be pressurized and, ideally, should not allow infiltration. Convectors are normally used only under outside windows. Interior spaces are heated by warm air, forced-circulation systems that use hot-water heating coils in the air-handlers. These systems are usually total environmental control systems that both heat and cool as required. The hot water temperature is regulated through a by-pass mixing valve according to the outside temperature. The mixing valve is located between the discharge side of the pump and the boiler water inlet. This temperature-regulated hot water is then pumped to the air handler and convector units where additional temperature controls maintain individual room or zone conditions. Some older buildings have modified systems where original steam radiators have been converted to hot-water radiators. These systems become closed-loop systems, and it is essential that no air enters the system. Expansion tanks are installed to allow for expansion of the hot water, and all air vents or vacuum breakers originally installed as part of the steam system are removed or closed off with a handcock to prevent any loss of water from, or influx of air into, the system.

523 DIRECT-FIRED SYSTEMS

A direct-fired system consists of small unitary (package) units for heating, or for both heating and cooling, that are usually supplied with gas-fired heaters called duct furnaces (see Figure 5-1). The heating section or duct furnace may be built into the same housing that enclosed the fan, filters, and cooling



VIEW A



VIEW B

Figure 5-1

DIRECT-FIRED SYSTEM WITH DUCT FURNACE

coil or it might be installed in the discharge duct of a packaged chiller unit. The duct furnace is a gas-tight enclosure where the hot combustion gases pass through a series of small flue pipes that are enclosed by the ductwork carrying the system air supply. The control unit uses a time-delay, spark-ignited pilot light, a flame-sensing element, combustion airflow switch, and high-temperature safety thermostat. The burner unit is ignited depending on a predetermined temperature of the room or return air. When the air requirement for the system exceeds the cfm capacity of the furnace section, it is customary to install a bypass duct around the furnace section. Bypass air can then be adjusted with a manual volume damper to ensure maximum permissible airflow through the furnace. Small direct-fired space heaters are used to some extent in small buildings that usually require no heat or that do not have a central system. This type of heater is usually ceiling-hung in the space to be heated and consists only of a fan, furnace, burner, and simple control system.

530 UNFIRED PRESSURE VESSELS

531 GENERAL

Any tank or metal container that is designed or used to contain liquid or gas under pressure and that is not heated by combustion of some type, is an unfired pressure vessel. Unfired pressure vessels are found throughout our mechanical systems. If superheated steam or high-temperature hot water is used to operate a low-pressure steam boiler, the boiler is classified as an unfired pressure vessel. The storage tank for an air compressor and the evaporator and receiver in an air-conditioning system are all unfired pressure vessels and may require periodic inspections. Consult Handbook HBK MS-1, Operation and Maintenance of Real Property, for inspection requirements.

532 CONSTRUCTION

In order to obtain maximum strength with the simplest construction methods, almost all pressure vessels used for high pressure or high temperature are constructed in a cylindrical shape. The ends of the cylinder or drum are either convex or concave. All pressure vessels are designed, constructed, and inspected according to strict codes; the American Society of Mechanical Engineers (ASME) code is accepted almost worldwide. A pressure vessel is built for a particular application or requirement and is checked, tested, and stamped by authorized code inspectors before it leaves the factory.

WARNING

The use of a pressure vessel for other than its intended purpose invites serious trouble and possible death and destruction. The same warning applies to altering or changing the vessel or safety device in any manner.

533 ASME APPROVAL

533.1 Code Stamp

The ASME code stamp should always be visible. It should never be defaced or removed. Code stamping on the cylinder usually shows the following data:

a. Operating pressure is the pressure normally expected in the system.

b. Maximum allowable working pressure (MAWP) is the maximum pressure that can be safely contained by the vessel. The setting of the pressure relief device must never be adjusted higher than the MAWP.

c. Design pressure may be shown and may be the same as MAWP or lower, depending on construction. Operating pressure must never be higher than design pressure.

533.2 Temperature

Temperature affects the strength of vessel material and as it increases, MAWP goes down. If the vessel is under hydrostatic pressure (no gas), the MAWP will decrease as the temperature of the liquid goes above 60 °F.

540 BOILER PRINCIPLES

541 APPLICATION

Generally, fire-tube boilers are used for low-pressure applications and water-tube boilers are used for high-pressure applications. Most of the present post office steam-heating systems use fire-tube boilers or cast-iron sectional boilers. High-pressure steam boilers are used if high-pressure steam is needed to operate equipment such as steam turbines for air-conditioning or large kitchens. Hot-water systems are specified for new post office buildings, and many older facilities have been converted to hot water. Most of these boilers are the fire-tube type and are bought as package boilers.

542 ALTERNATIVE FUEL SOURCE FEASIBILITY--FUEL-OIL FIRED BOILERS

No replacement burners may be installed on fuel-oil fired boilers without first evaluating the feasibility of modifying the boiler use modification to an alternate fuel source. This same evaluation must be performed prior to any major modification or repair of the boilers.

543 LOW-PRESSURE BOILERS

Boilers classified as low-pressure boilers must not exceed 15 psig steam pressure or 160 psig water pressure when used as hot-water boilers. Low-pressure boilers are further classified according to the material from which they are fabricated and are either steel or cast-iron boilers. They are also classified by the position of the combustion gases with respect to the tube surface and as either fire-tube or water-tube. In a fire-tube boiler, the hot combustion gases travel through the fire-tube boiler and contact the inside surface of the fire tubes that are surrounded by water. In a water-tube boiler, the combustion gases travel around the tubes and the tubes are filled with water.

544 HIGH-PRESSURE BOILERS

Boilers rated to operate at steam pressures above 15 psig and water pressures above 160 psig, and/or at temperature over 250 °F are classified as high-pressure boilers by ASME and are referred to as power boilers. They may be of either fire-tube or water-tube design. Cast-iron boilers are not used for high pressure. Although there are a few high-pressure steam boilers in postal facilities, they are not covered in this handbook. Manufacturers' manuals and operating instructions should be consulted on high-pressure boilers.

545 HOT-WATER BOILERS

New heating systems in postal facilities are generally designed for hot-water heating. Hot water is pumped throughout the building without the use of large steam lines and the consequent problem of returning the condensate to the boiler. Hot water is easier to control than steam and results in a more smoothly balanced system. A hot-water boiler is the same as a steam boiler, except that it is part of a closed system and is entirely under a constant water pressure. There is no water column or gauge glass on the boiler as the entire boiler is flooded. The water is heated as it circulates through the boiler. An expansion tank is required to water as it is heated and cooled. Enough pressure must be maintained on the entire system to ensure a few pounds of pressure at the highest point in the system when the hot-water circulating pump is off. The pressure is maintained by a charge of air or nitrogen that expands or compresses as the water contracts or expands. The charge of air or nitrogen is contained in the expansion tank. Hot-water systems are classified according to the water temperature maintained and are divided into three ranges. Low-temperature hot-water (LTHW) systems range from 180 to 250 °F; medium-temperature hot-water systems range from 251 to 300 °F; high-temperature hot-water systems range from 301 to 400 °F. All postal installations having hot-water heating systems operate in the LTHW range and normally operate at 210 °F or lower.

546 BASIC TERMINOLOGY

546.1 Saturated Steam

Saturated steam has a temperature equal to the saturated or boiling temperature of water, depending on the existing pressure. As an example, the boiling temperature of water under a pressure of 10.3 psig from Table 12, Appendix A, Water/Steam Table, is shown to be 240.1 °F. Because of the pressure, the water must be heated to 240.1 °F before it will boil. The saturated steam temperature would also be 240.1 °F. A related temperature exists for all pressures and by knowing either the temperature or pressure, the other can be found from Table 12, Appoendix A.

546.2 Superheated Steam

Superheated steam is steam that has reached a temperature higher than the saturation or boiling temperature for the existing pressure. This is accomplished by further heating the saturated steam after it is separated from the boiler water. As long as the steam is in contact with the water, additional heat added will boil more water into saturated steam and will not raise the temperature of the steam. Superheaters are common on high-pressure boilers but are seldom used or needed on low-pressure units.

546.3 Boiling and Circulation

.31 **Boiling.** Steam is formed in bubbles along the tube surface that is exposed to the boiler heat. This is called boiling. The greater the temperature difference between the heated surface and the water, the faster the heat will pass through the tube wall to the water and the faster the steam will be formed.

.32 **Circulation.** One of the main considerations in boiler design and construction is the circulation cycle. The boiler must be designed and built so that all phases of the circulation cycle work together to create a system that is safe in operation and is as efficient and economical as possible. Due to differences in water temperature within the boiler, a definite circulation pattern is established which results in completion of the following three steps common to all boilers:

a. Flow of water to heated areas

b. Flow of steam and heated water to upper areas

c. Release of steam

546.4 Btu Input

Btu input is a measure of the amount of fuel the boiler can burn safely per unit of time. Every type of fuel has a definite heat content or Btu rating per pound, gallon, or cubic foot. The operator should know the Btu rating for the fuel being burned. Input rating is usually given in Btus per hour. It is also called combustion rate.

546.5 Btu Output

The amount of steam produced per hour is measured and converted to Btu by the use of a steam chart. A pound of steam contains a certain number of Btus depending on its temperature and pressure.

546.6 Boiler Horsepower

Although the term "boiler horsepower" is obsolete, it is still used in reference to the boiler capacity of old boilers. A boiler horsepower is equal to the evaporation of 34.5 pounds of water at a temperature of 212 °F into steam at a temperature of 212 °F. This is 34.5 times the latent heat of vaporization of one pound of water at atmospheric pressure or 33,472 Btu\hr.

546.7 Pounds of Steam Per Hour

Boilers are rated in pounds of steam per hour at a specified temperature and pressure. This rating is the standard for high-pressure industrial boilers. A steam-flow meter, or a steam-integrator meter is used to read or record pounds of steam per hour. Operation of a boiler in excess of its rating can burn the heating surfaces and destroy the boiler.

WARNING

A boiler must never be fired higher than its rating.

546.8 Square Foot Heat Transfer Area

This is a measure of the boiler surface area that is used to transfer heat into the boiler water. The tube surface area constitutes the majority of this area. It was common practice years ago to rate 1 boiler horsepower as 10 square feet of heating surface. New boilers are now rated as high as 3 square feet per each boiler horsepower, but 5 square feet is considered normal.

547 LOW-PRESSURE BOILER DESIGNS

547.1 General

Low-pressure boilers are used to heat water that is used for space heating purposes, or they are used to produce saturated steam at a pressure under 15 psig. Basically, a low-pressure steam-heating boiler produces steam at a pressure just high enough to do a satisfactory job. The steam is saturated but should not contain the droplets of water known as priming or carryover. The steam condensate is returned to the boiler with as little loss of condensate as possible. Makeup water is added to the boiler to replace any loss of steam or condensate. Some type of fuel is mixed with air and burned in the boiler to produce the heat that is transferred to the boiler water. The true efficiency of the boiler is determined by comparing the total heat in the steam produced to the total heat in the fuel used. How the fuel is burned, how the heat is transferred to the boiler water, how efficient the boiler is, etc., are all related to the type of boiler, how it is designed and built, the type of fuel used, the pressure maintained in the boiler, and how it is operated and maintained. Figure 5-2 illustrates a typical low-pressure boiler.

547.2 Basic Types

The most common boilers are fire-tube multipass internal combustion, package hot-water boilers (see Figure 5-3). Some types are: two-pass firebox boilers, horizontal return-tube boilers, two-pass portable firebox boilers, and locomotive boilers. Each of these boilers, plus many others, are in use today. Each name is descriptive of a certain type of boiler and provides a fairly good description of a heating plant when included with boiler rating and type of fuel used.

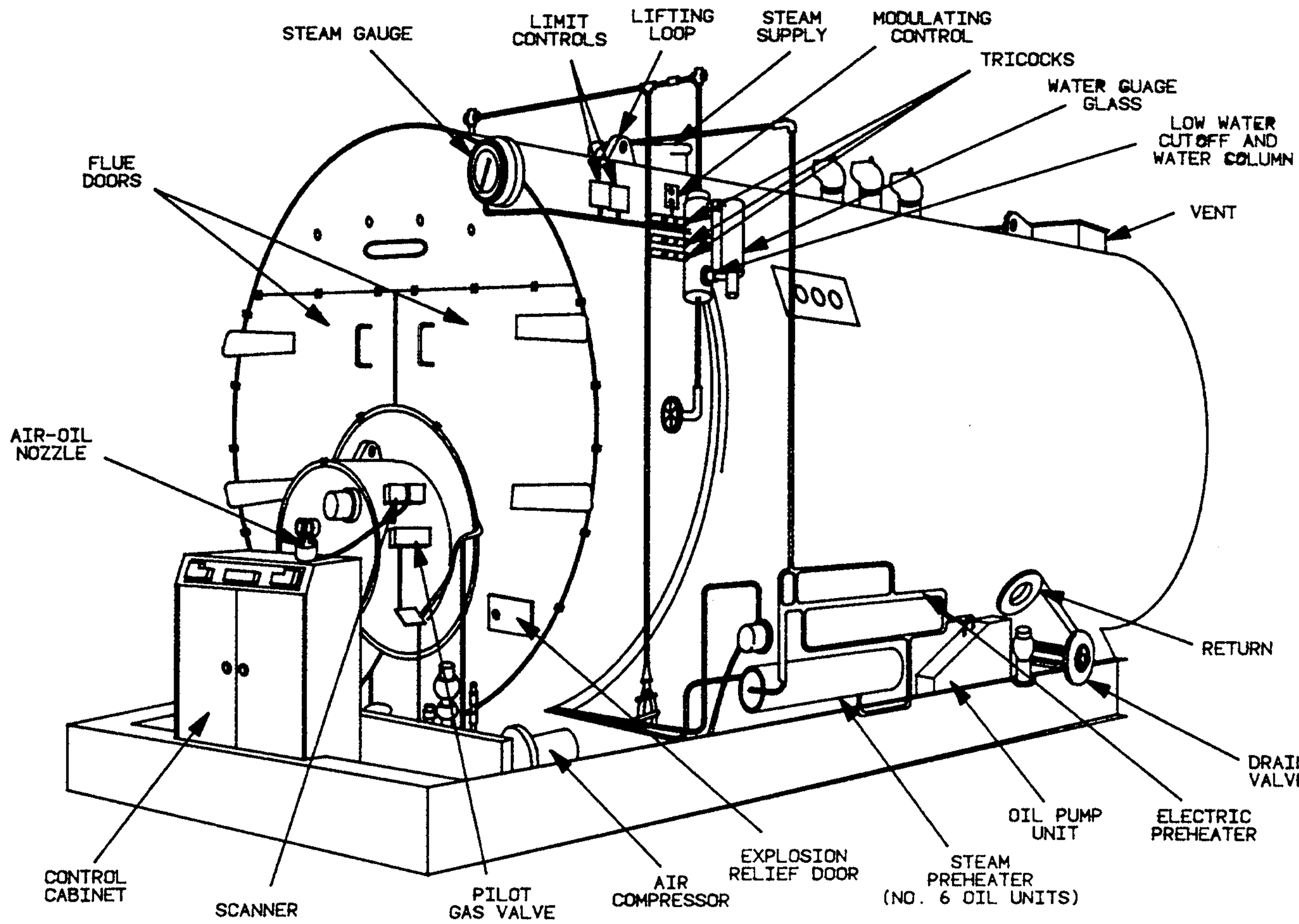


Figure 5-2

TYPICAL LOW-PRESSURE PACKAGE BOILER

547.3 Boiler Appearance and Construction

.31 **Simple Drum Boiler.** The first boiler used was a simple shell or drum with a feedwater line and a steam outlet mounted on a brick setting with a firebox underneath. Fuel was burned on a grate, and the heat was directed over the lower shell surface before most of it went out the flue. It was soon determined that this method was very inefficient, and it was necessary to bring more of the water into better contact with the heat to reduce heat loss and to boil water faster.

.32 **Fire-Tube Boilers.** The forerunner of modern fire-tube boilers and the first boiler to use fire tubes is commonly called the horizontal return-tube (HRT) boiler (see Figure 5-4). Tubes were installed through the boiler shell, and the flue installed on the front of the boiler. The heat was directed over the bottom of the shell

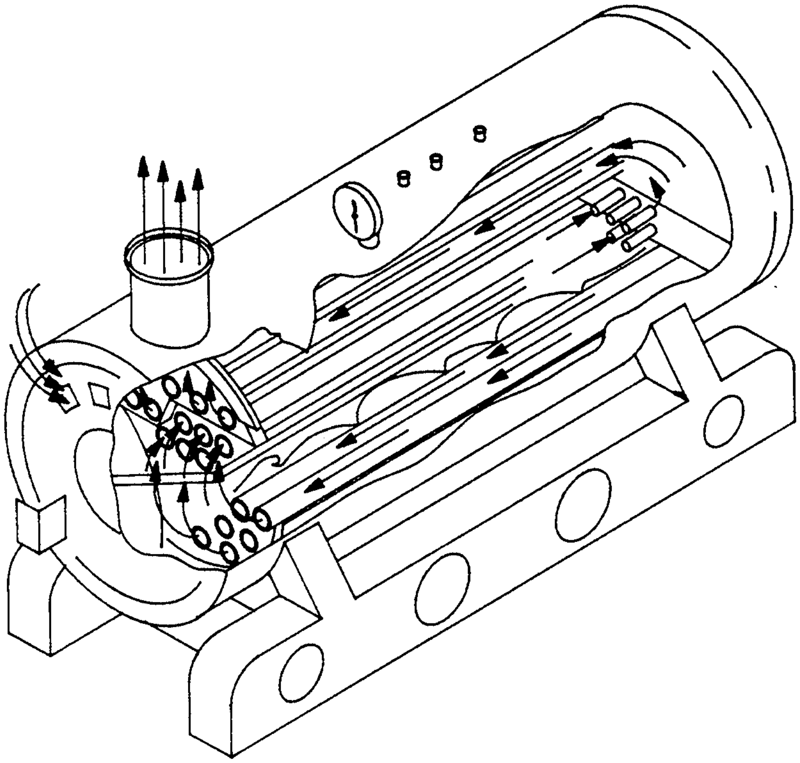


Figure 5-3

PACKAGE FIRE-TUBE BOILER

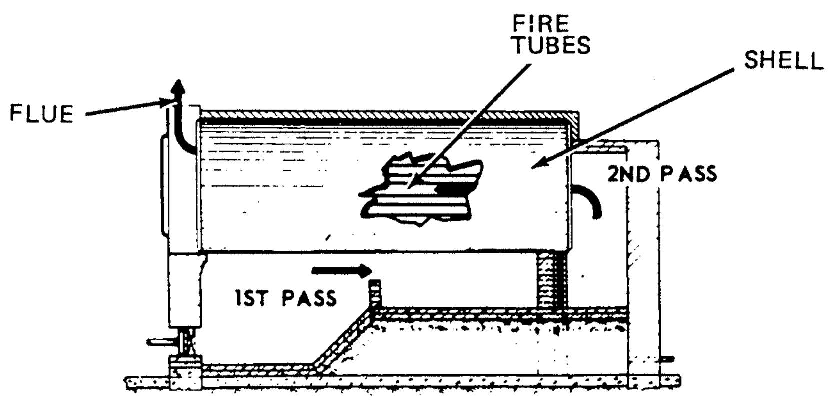


Figure 5-4

HRT BOILER

and then passed through the fire tubes back to the flue at the boiler front. This was the forerunner of modern fire-tube boilers.

.33 **Firebox Boiler.** This type of boiler is a two-pass horizontal steel boiler that usually has the firebox built in at the factory. The firebox or combustion area may be enclosed with a water leg on the sides or may have some type of water wall tube arrangement for reducing waste heat. The burners and boiler fittings are installed at the facility after the boiler is installed. Another firebox-type boiler has the firebox built from firebrick after the boiler is set in place (see Figure 5-5).

.34 **Internal Furnace or Marine Boilers.** These boiler types represent the largest number of boilers being sold for building heating systems. They are also referred to as package boilers, since they usually come completely equipped with burner, controls, and all auxiliaries. These boilers are prefired and tested before shipment and are built with two to four multipasses. These boilers are fired on gas or liquid fuels, and combustion takes place in the first pass of the boiler. They are built with a dry back, refractory-lined rear chamber or with a wet back where the rear chamber is covered by a water shell that is an extension of the boiler drum. Scotch boiler is the name given to the dry back boiler, internal furnace, or package boiler. Scotch marine boiler is the name given to the wet-back-type package boiler (see Figure 5-6). Additional passes of flue gas through a boiler increase its efficiency by removing more heat from the flue gas before it leaves the boiler. This process allows the use of a smaller boiler size to produce a rated load. Improvements in design of both boilers and burners allow for greater heat transfer, and the two-pass boilers are now capable of extracting most of the heat from the gases. This makes the two-pass boiler somewhat lower in initial cost. Internal furnace fire-tube boilers are also used for high-pressure steam applications up to 250 psi and 25,000 pounds/hr. They are also used as hot-water boilers for both low and medium hot-water temperature applications.

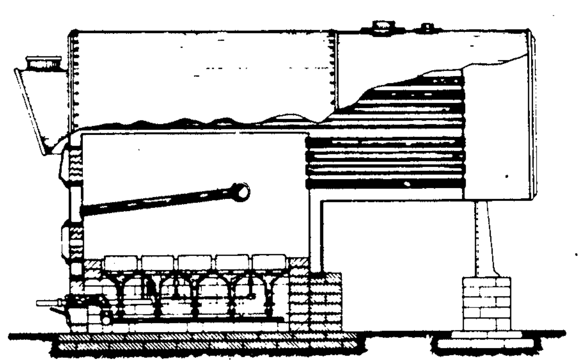


Figure 5-5
SHORT FIREBOX BOILER

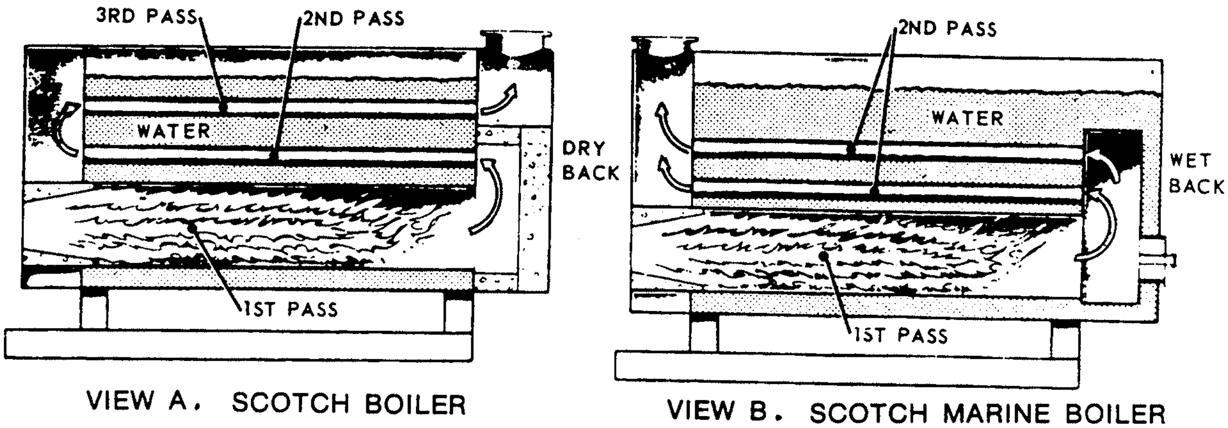


Figure 5-6
SCOTCH BOILER DESIGNS

.35 **Vertical Boilers.** Vertical boilers are fire-tube boilers used for small system applications (see Figure 5-7). Modern vertical boilers are very efficient in operation, require very little floorspace, and are used for both low- and high-pressure application. The fire tubes in these boilers are usually either equipped with helical inserts that spiral the gas against the tube surface or constructed with internal fins to increase the heating surface. One type is a two-pass boiler with forced-draft burner.

.36 **Electric Boilers.** Electric boilers are also used for small plants or for special applications. They are usually contructed of a vertical shell-type design. Heat is generated by metal electrodes submerged in the water using the boiler as the conductor. Low-water protection is automatic, because current will not flow above the water level. These boilers are usually used as auxiliary heating units in total electric systems using the heat-pump principle. Water-treatment to improve the conductivity of the water is usually required to maintain maximum output.

.37 **Hot-Water Boilers.** The fire-tube hot-water boilers are very similar to steam boilers in appearance and, except for a few differences, are basically constructed and operated the same way. Instead of controlling steam pressure with a pressurestat, temperature is controlled with an aquastat. The water column, water glass, and gauge cocks are not needed since the boiler is completely filled with water. Likewise, dry pipe baffles are not needed. In place of a steam outlet pipe, provisions are made for plumbing a water inlet and outlet. The interior of the

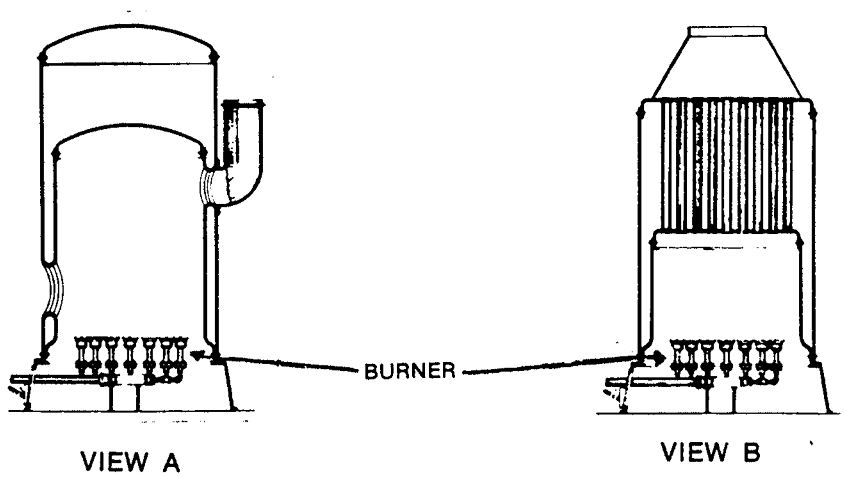


Figure 5-7
VERTICAL FIRE-TUBE BOILER

boiler is designed so that water will circulate through the boiler and not short-circuit from the inlet to the outlet connections.

.38 **Cast-Iron Sectional Boiler.** A cast-iron sectional boiler is commonly used for small buildings to generate steam or hot water. This type of boiler is constructed of several sections of hollow castings and is similar in construction to the old cast-iron radiators. The sections are connected to each other at top and bottom by swedge nipples and tough-bolts. Water glass and try cocks are installed directly on one of the cast-iron end sections. Combustion takes place below the boiler itself, and hot gases pass up and through the cast-iron sections.

.39 **Other Boilers.** Other boilers are as follows:

a. Water-Tube Boilers. Water-tube boilers are classified as straight-, curved-, bent-tube boilers. They are also classified according to the number of drums used: single-drum, two-drum, three-drum, or multidrum boilers. They are adaptable for high-pressure use since drums can be kept small, and all steaming is in the water tubes outside the drums. Small water-tube boilers require only one drum in which the water level is maintained and the steam is released. When the boiler size is increased, additional drums are used instead of increasing the drum size. Increasing the drum size would require increasing the drum metal thickness. In a fire-tube boiler when the pressure is doubled or the diameter of the drum is doubled, the thickness of the drum metal must also be doubled. If both the diameter and pressure are doubled at the same time, the drum metal thickness would quadruple. This is what limits pressure and size of fire-tube boilers.

b. Water-Level Steam Boilers. In water-level steam boilers, the boiler drum of the fire-tube boilers must have an open space for steam above the top row of fire tubes. The water level is maintained in the drum so that the fire tubes are always covered by water. If the water level is allowed to drop to a point where tubes are not covered by water, they will overheat and burn out or rupture.

548 BOILER CLASSIFICATIONS AND COMPONENTS

548.1 Classifications

The two general classifications of heating boilers pertain to the method of manufacture: casting or fabrication. Cast boilers are usually made of iron, bronze, or brass. Fabricated boilers are generally made of steel but can also be copper or brass.

548.2 Fabricated Boilers

.21 **General.** Steel boilers can generally be divided into two types: fire-tube and water-tube. In fire-tube boilers, the combustion gas passes through the tubes and the water circulates around them. In water-tube boilers, the water passes through the tube and the combustion gases pass around them.

.22 **Fire-Tube Boilers.** Types of fire-tube boilers are as follows:

a. External-Furnace Boilers (HRT). In this type of boiler, the furnace is external and may be brick-set or steel-jacketed. It is surrounded essentially by a refractory rather than by water.

b. Scotch Boilers. The scotch boilers used in modern heating systems are similar to those originally designed for shipboard installation and are sometimes called scotch marine boilers. The furnace is a cylinder completely surrounded by water. Most scotch boilers are of the dry back or partial wet back design and are arranged for multiple gas passes.

c. Firebox Boilers. Firebox boilers have a firebox integral with the boiler, such as the oil field- or locomotive-type, and may be single or multiple pass. The furnace of this boiler is usually enclosed in a water-cooled upper sheet called a "crown sheet." Various tube and shell configurations characterizing different manufacturers' designs complete the boilers.

d. Vertical Fire-Tube Boilers. In vertical fire-tube boilers, the products of combustion pass up through tubes surrounded by water.

.23 **Water-Tube Boilers.** Water-tube boilers are made in a variety of configurations with respect to tube and drum arrangement. Field maintenance personnel must not "pop test" water-tube boilers by firing the unit unless USPS boiler inspectors are contacted for technical advice.

548.3 Cast-Iron Boilers

.31 **General.** Cast-iron boilers are made in three general types: horizontal-sectional, vertical-sectional, and one-piece. Most of the sectional boilers are assembled with push nipples, but some are assembled with external headers and screwed nipples.

.32 **Horizontal-Sectional.** Horizontal-sectional, cast-iron boilers are made up with sections standing horizontally like the slices in a loaf of bread.

.33 **Vertical-Sectional.** Vertical-sectional, cast-iron boilers are made up of sections stacked one above the other, like pancakes, and assembled with push nipples.

.34 **One-Piece.** One-piece, cast-iron boilers are those in which the pressure vessel is made as a single casting.

548.4 Components

.41 **Boiler Body.** Older boilers were constructed in a cylindrical form with flat tube sheets at both ends where fire-tubes were attached. The metal was high-grade steel commonly referred to as boiler plate steel. Modern boilers are usually in a cylindrical form but have many configurations due to modern methods of welding and internal bracing. The old lap joints used for joining metal with rivets have been replaced with stronger, welded joints. All boiler construction methods are rigorously governed by codes and ordinances. The most important code used in construction of pressure vessels is the one sponsored by ASME. All boilers in postal facilities must be manufactured according to the ASME code and stamped with the code stamp indicating code compliance.

.42 Fire Tubes. The fire tubes act as braces for the flat tube sheets to which they are attached and are either rolled, welded, or both. In any case, they extend through holes in the tube sheet and are either rolled and beaded or rolled and welded on the outside of the tube sheet so that any individual tube can be replaced as needed. Tubes in fire-tube boilers are sometimes called flues; however, it is the usual practice to use this term only for large pipes found in older boilers. Flues are usually 6 inches or larger in diameter, whereas the small tubes are 2 to 3 inches in diameter. There are no standard sizes for fire tubes; therefore, many different sizes exist. When it is necessary to replace a tube for any reason, follow these procedures:

a. Remove the tube without cutting or defacing the tube sheet in any way.

b. Check inside the boiler by looking through the tube opening to determine the condition of the other tubes in the same area.

c. Check the removed tube to determine exactly what caused the failure and to see if scaling or corrosion is taking place in the boiler. If the tube shows evidence of pitting corrosion, it is more likely that the surrounding tubes are also pitted and should be replaced before they fail.

d. If the tubes are rolled, use a special reamer to clean, deburr, and countersink the tube opening before any new tubes are installed.

e. Clean the new tubes inside and out before installing unless it is intended to boil out the entire boiler before it is put back into service.

f. Use special tube expanders and beading tools for different size tubes. It is very important that the person doing the work use the right tools and fully understand their usage. Otherwise, the tube may leak.

g. If the tubes are welded, grind the ends of the replacement tube smooth and flat and then bead them so that no metal except the tube head extends past the tube sheet. This prevents overheating or melting of the tube metal which might extend past the water-covered tube sheet.

.43 Bracing. Boilers require internal bracing to withstand pressure and temperature changes. Drum ends and tube sheets are usually the weak links in fire-tube boilers and they require most of the bracing. As mentioned in Section 548.42, the tubes act as bracing for the flat tube sheets, but additional bracing is usually required. Threaded through-stays are used on older boilers, and these must be checked and kept tight. These staybolts may also be "drilled stays" that have a small hole drilled in the center of the staybolt extending 6 inches into the bolt. The drilled hole will leak if the staybolt cracks within the drilled area. Newer boilers use welded stays. Although all supporting members are called stays, a "brace" is usually defined as a large stay. Stayrods are used like stay bolts on older boilers and may be equipped with turnbuckles for adjustment. Other types of stays used are gusset, palm, diagonal, jaw, crowfoot, radial, etc. All stays and bracing should be checked when a boiler is given an internal cleaning or inspection. Dry pipe is a term used to describe the steam-collection piping at the top of the boiler drum and above the open space over the water level. Most boilers have some type of piping arrangement that acts to prevent drops of water being carried by the steam into the steam-line outlet. The arrangements vary from a simple pipe drilled with holes for the steam to enter to a complicated baffle arrangement that acts as a water trap.

550 BOILER AND BOILER ROOM ACCESSORIES

551 SAFETY AND PIPING CONTROLS

551.1 Safety Valve

The safety valve is attached directly to the boiler steam drum and relieves excess boiler pressure when it exceeds the boiler-control settings and reaches the pressure setting of the valve. The safety valve(s) must be capable of relieving steam pressure from the boiler fast enough to prevent the pressure from rising above the valve-popping pressure. If the boiler is operating at 100 percent of capacity and the main-stream stop valve is closed, all the steam produced can be relieved by the safety valve, if it is designed and operating properly. A safety valve is an automatic pressure-relieving device actuated by the pressure generated within the boiler. It is used primarily on steam boilers. Valves of this type are spring-loaded with a factory-sealed pressure setting (see Figure 5-8).

551.2 Safety-Relief Valve

This valve is attached directly to the drum of a hot-water boiler to relieve excess boiler pressure when it exceeds the boiler-control settings and reaches the pressure setting of the valve. The steam boiler safety valve must relieve steam pressure from the boiler and the safety-relief valve must relieve excess water volume from the hot-water boiler. Although the two valves have the same basic purpose, they are not identical valves and must be used only for their intended purposes (see Figure 5-9).

551.3 Water-Level Controllers

Although some older boilers still depend on a manually opened valve to add water to the boiler, most boilers are equipped with some type of automatic water-level control. The most common is a float-type that admits makeup water directly to the boiler. Other float-types are used to open valves or makeup contacts that start up a pump or energize some device to admit water to the boiler. An electric probe or set of probes is the other main type of water-level controller. When the water level drops enough to uncover a probe, the electric current is stopped between the probes or between a probe and the boiler metal. This interruption in current is a signal to add water to the boiler until the probe is again covered by the water and the current is again established.

551.4 Low-Water Fuel Cutoffs

.41 Types. A low-water cutoff is very similar to the water-level controller and, in many cases, may be combined with the level controller to perform both functions. The low-water fuel cutoff may be float-operated or may be the electric-probe-type, but the purpose of the device is the same. Low-water fuel cutoffs are designed to provide protection against hazardous low-water conditions in heating boilers. Records indicate that many boiler failures result from low-water conditions. Low-water fuel cutoffs may be generally divided into two types: float and probe (see Figures 5-10 and 5-11).

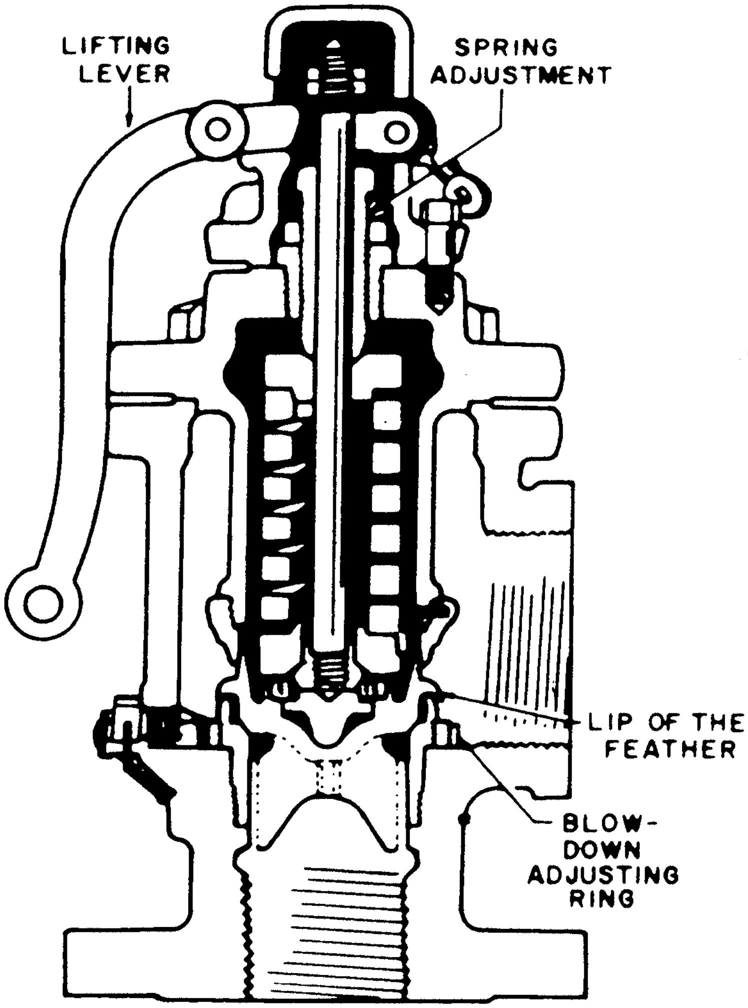


Figure 5-8

CROSS SECTION OF SAFETY VALVE

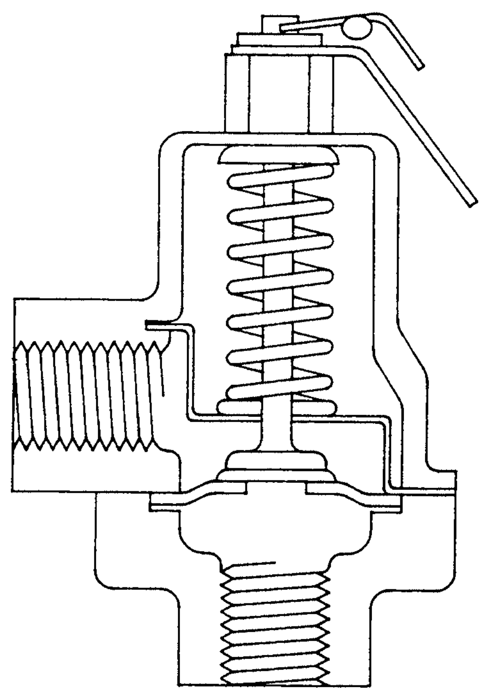


Figure 5-9

SAFETY RELIEF VALVE

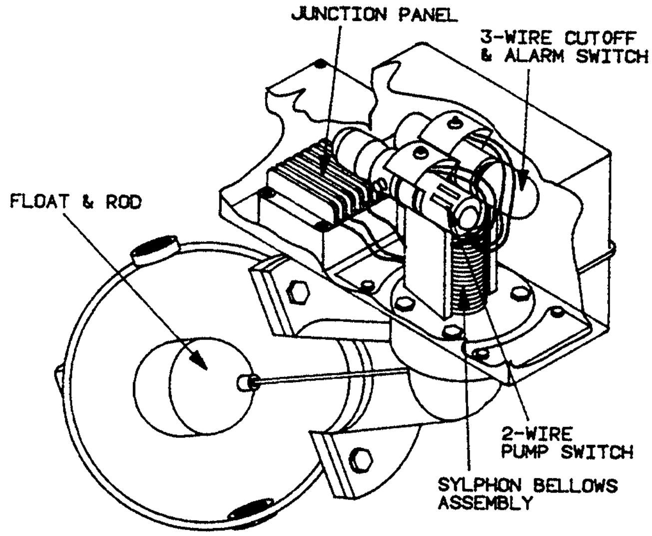


Figure 5-10

FLOAT-TYPE LOW-WATER FUEL CUTOFF WITH MANUAL RESET

.42 **Combination Low-Water Cutoff and Boiler Feeder.** Float-type, low-water fuel cutoffs may be combined with a water feeder or built as a separate unit. The combination feeder cutoff units are generally used on steam boilers, while the cutoff units are sometimes installed on hot-water boilers or as a second cutoff on steam boilers. A feeder-cutoff combination adds water as needed to maintain a safe minimum water level and stops the firing device if the water level falls to the lowest permissible level. Both operations are accomplished by the movement of the float, linked to the water valve or pump control and burner-cutoff switch. The units serving as fuel cutoffs only are basically the same as the combination unit, but without the water-feeder valve (see Figure 5-12). A water-feeder installation normally acts as an operating control to maintain a predetermined safe water level in the boiler. If the installation is designed to maintain a safe water level with the safety or safety relief valve discharging at capacity (steam and/or hot-water boilers), it can be considered a safety control.

.43 **Electric Probe-Type, Low-Water Fuel Cutoffs.** Electric probe-type, low-water fuel cutoffs are either contained in the water column mounted externally on the boiler or mounted on the boiler shell. Some consist of two electrodes (probes) that, under normal conditions, are immersed in the boiler water with a small current being conducted from one electrode to the other to energize a relay. Others use one probe, and the boiler shell, in effect, becomes the other probe. If the water level drops

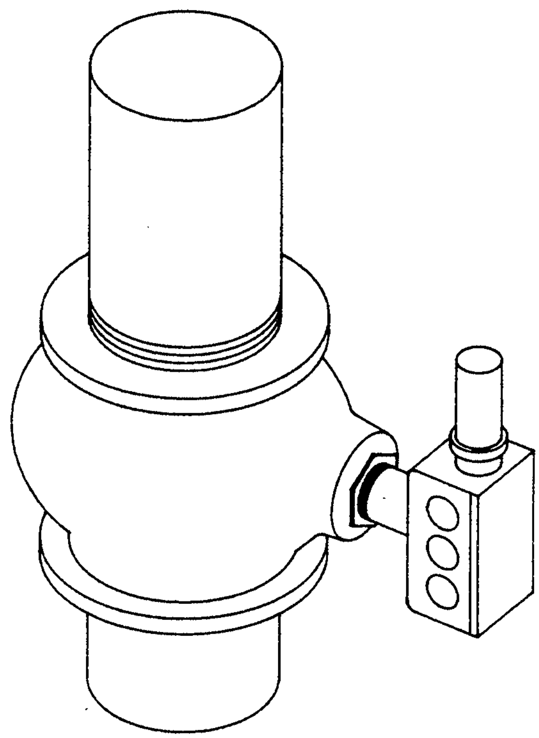


Figure 5-11

ELECTRIC-PROBE LOW-WATER CONTROL

low enough to uncover the probes, the current flow stops and the relay operates to shut off the burner (see Figure 5-11).

551.5 Traps

A steam trap is a device put on steamlines and on the outlet of heating units to permit the exit of air and condensate and prevent the passage of steam. The types of steam traps commonly used are as follows:

a. Thermostatic (See Figure 5-13A.)

b. Float (See Figure 5-13B.)

c. Combination float and thermostatic (See Figure 5-13C.)

d. Bucket (See Figure 5-13D.)

551.6 Air Eliminators

Air eliminators are installed on hot-water boilers to eliminate air from the system as it is released from the water within the boiler (see Figure 5-14)

551.7 Condensate-Return Pumps and Return Loop

Condensate-return pumps are used on either one- or two-pipe steam systems to return condensate to the boiler when this cannot be done by gravity. They are generally used in conjunction with a reservoir (condensate-return tank) and a float-operated switch for starting the pump motor. Where two boilers are connected together and served from one condensate-return pump, a vacuum breaker may be required on the idle boiler to prevent the formation of a vacuum which

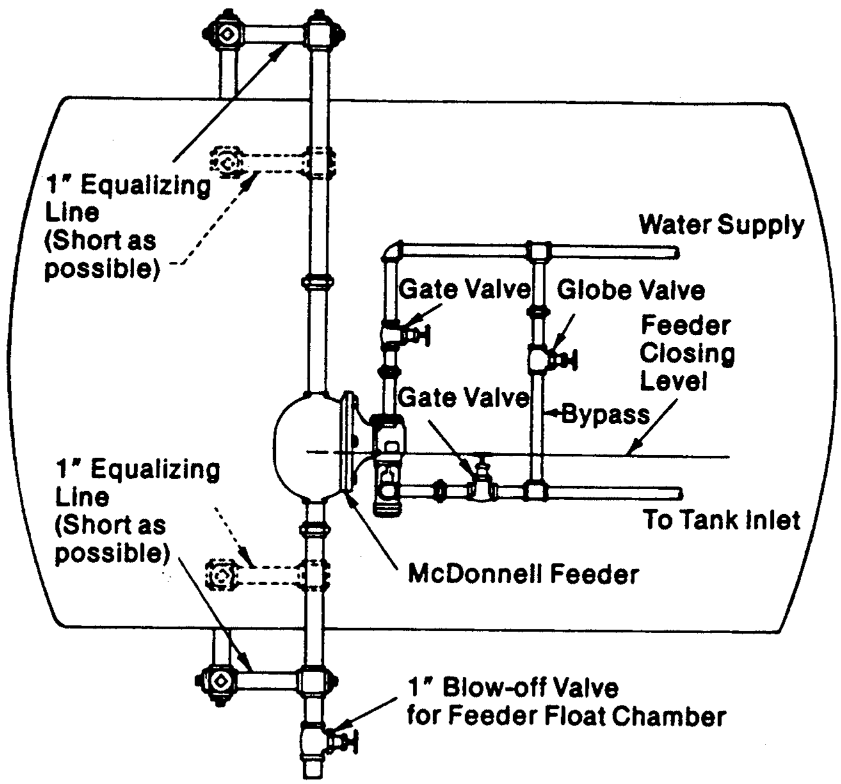


Figure 5-12

INSTALLATION OF COMBINATION LOW-WATER FUEL CUTOFF AND BOILER WATER FEEDER

would affect the functioning of the feed valve. Each boiler of a steam heating system must have the return-pipe connections that supply a gravity return arranged to form a loop as shown in Figure 5-15. This ensures that the water in each boiler cannot be forced below the safe water level. The loop is required in gravity systems and is desirable in pump-return systems. This is called a Hartford loop.

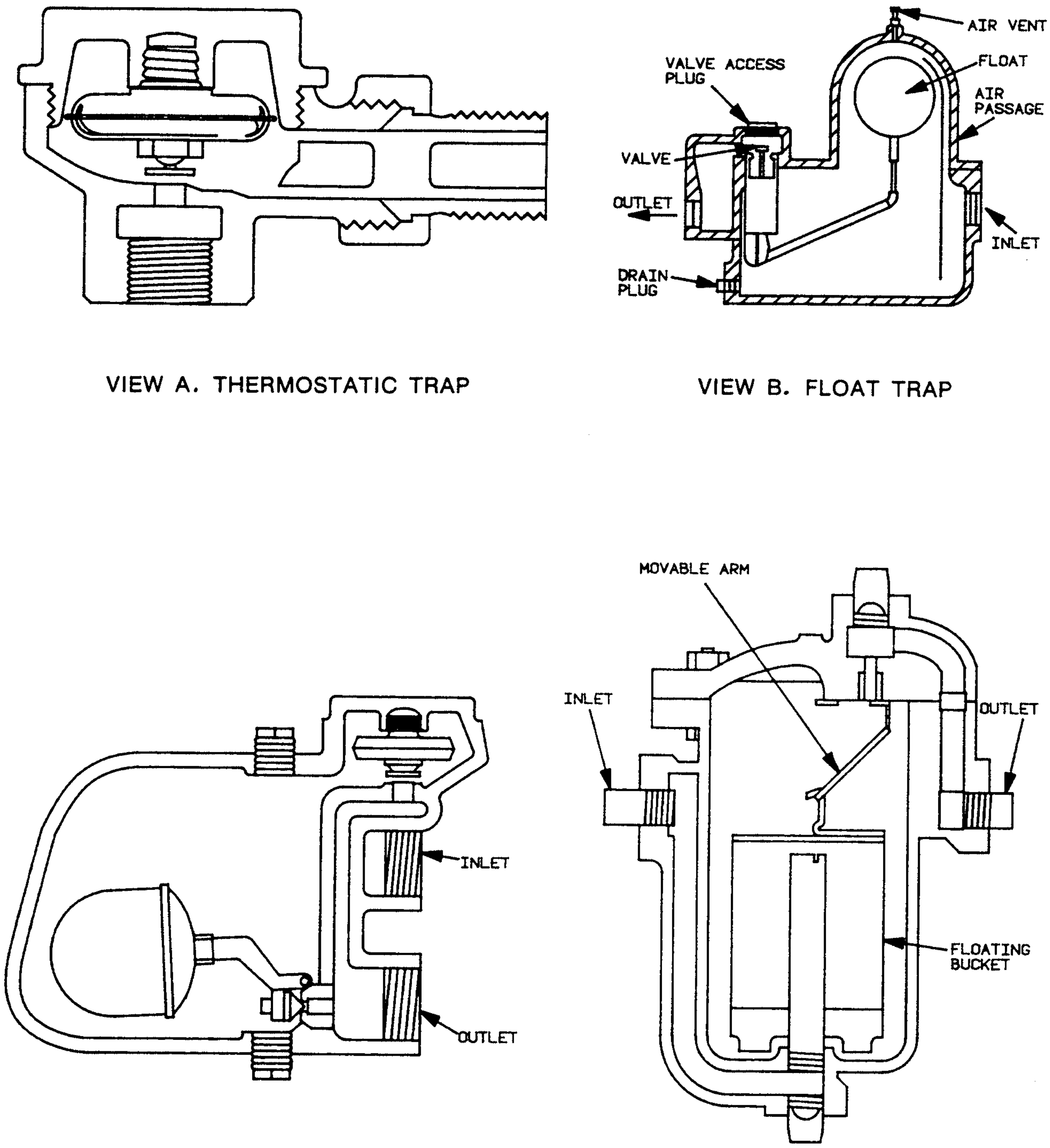
551.8 Vacuum-Return Pump

The vacuum-return pump is used in larger systems to create a partial vacuum in the return lines of the heating system and to assist in condensate return, air elimination, and steam distribution.

551.9 Other Controls

.91 Circulators (Circulating Pumps). Circulators are basically centrifugal-pump units used on hot-water heating systems to force the flow of water through the system.

.92 Expansion Tanks. Expansion tanks are used on hot-water systems to allow for the expansion of heated water. An air cushion in the tank is compressed by the expanding water. Hot-water heating systems are classified as closed-loop systems. This means the system is airtight and water or air cannot enter or leave the system. The entire piping system must be completely filled with water, and a minimum pressure of 2 or 3 psig is maintained at



VIEW A. THERMOSTATIC TRAP

VIEW B. FLOAT TRAP

VIEW C. FLOAT AND THERMOSTATIC TRAP

VIEW D. BUCKET TRAP WITH TRAP CLOSED

Figure 5-13

STEAM TRAPS

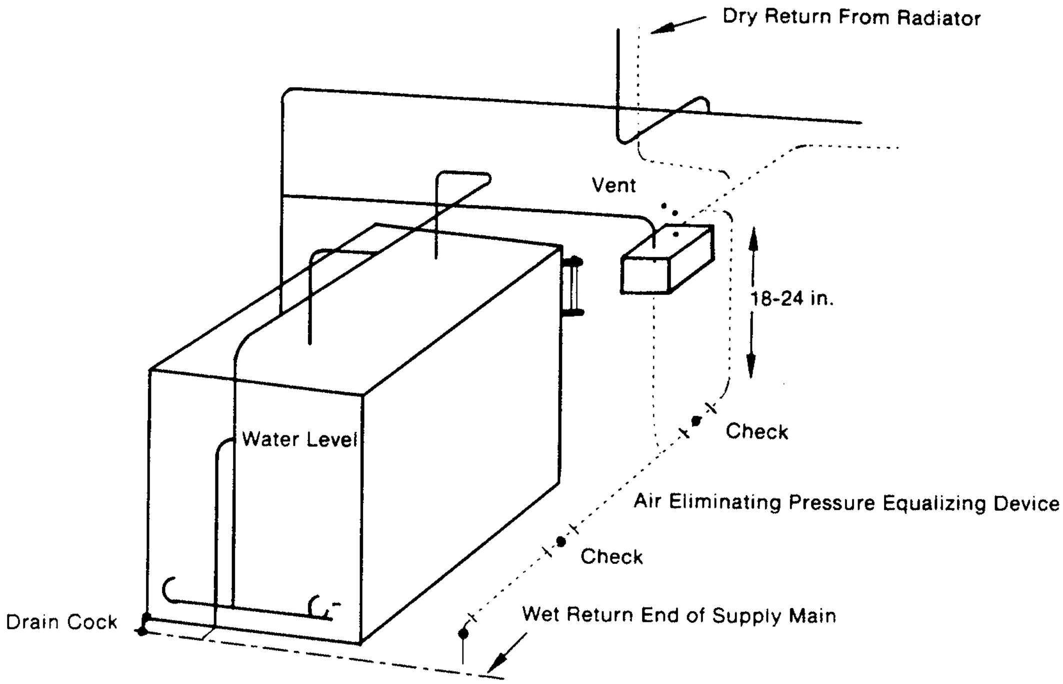


Figure 5-14
AIR ELIMINATOR

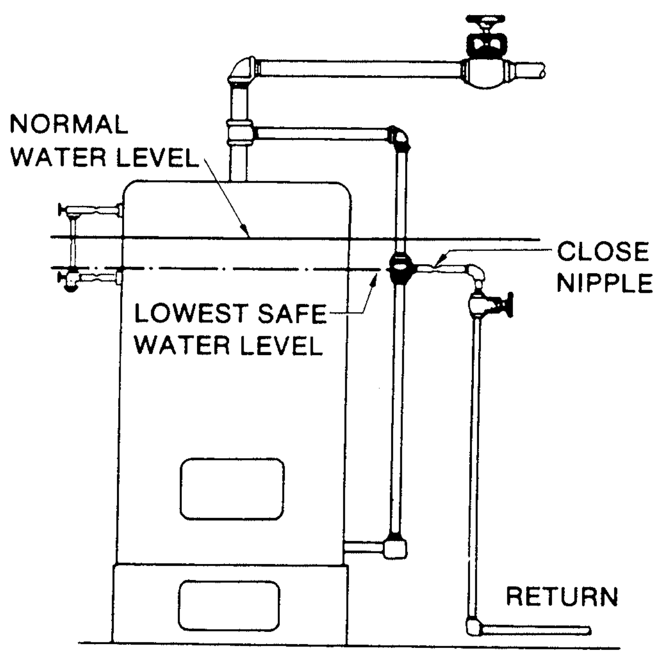


Figure 5-15
TYPICAL RETURN

the highest point in the system when the water in the system is cold and the circulating pump is off. This ensures that no air pockets may develop at high points in the system.

If any container is filled completely with water, sealed, and then heated, the water expands and the pressure increases rapidly until the container explodes; the same will happen in a hot-water system unless the system has some type of expansion tank with an air cushion. Water will not compress; the air in the expansion tank will. This allows heated water to expand by compressing the air in the tank. The pressure in the system increases as the water is heated. An expansion tank must be properly sized for the system and properly installed to do its intended job. It should be located higher than the hot-water boiler and connected into the system between the boiler's water discharge and the circulating-pump suction. This location helps stabilize the pressure throughout the system and increases the pump-suction pressure, making the pump more efficient. Air cushion bladder-types may be mounted anywhere.

.93 **Oil Preheaters.** Oil preheaters are used to condition the heavier grades of fuel oil for handling and burning. They are used in the oil storage tank or at the burner (or at both locations), depending upon the kind of oil burned.

.94 **Fuel-Oil Storage and Supply Systems.** A fuel-oil storage and supply system may consist of a tank connecting piping and necessary strainers only, or it may require a transfer pump, depending upon the location of the tank and the grade of oil being used. In cold climates where outside fuel-storage tanks are used for oils of Grades 4, 5, or 6, hot-water or steam-heating coils must be installed in the tanks. The fuel-oil temperature should be controlled to permit satisfactory flowing or pumping in the presence of low outside air temperatures.

.95 **Temperature and Pressure Controllers.** Boilers must have some way to maintain a constant pressure or temperature inside the boiler shell. One good method is to adjust or turn off the burner when the pressure reaches the desired point and turn the burner back on or increase the firing rate when the pressure starts to drop. This is the method used on modern boilers, and the devices used are called the pressurestat and aquastat. The pressurestat is a device that stabilizes or maintains a constant pressure. An aquastat maintains a constant water temperature. Steam boilers require pressurestats and hot-water boilers require aquastats. These controls are used either as a simple ON/OFF electric switch to make or break the burner circuit or to modulate or adjust the burner up or down to maintain constant pressure or temperature.

552 FUEL-BURNING EQUIPMENT AND FUEL-BURNING CONTROLS

552.1 Gas-Burning Equipment

.11 **Types.** Gas burners fall into two general classes: atmospheric and power.

.12 **Atmospheric Gas Burners.** Atmospheric gas burners depend upon natural draft for combustion air. There are several types of atmospheric gas burners, most of which are either single or multiport-type (see Figure 5-16).

.13 **Power Gas Burners.** Power gas burners depend upon a blower to supply combustion air. They fall into two general classifications:

a. Natural-draft burners. These operate with a furnace pressure slightly less than that of atmospheric burners. The proper draft condition is maintained by either natural draft or an induced-draft fan.

b. Forced-draft burners. These are designed to operate with a furnace pressure higher than that of atmospheric burners. Forced-draft burners are equipped with sufficient blower capacity to force products of combustion through the boiler without the help of natural or induced draft.

.14 Combination Fuel Burners. Combination fuel burners are designed to burn more than one fuel, with either a manual or automatic switchover from one fuel to another. The combinations of fuel generally used are natural gas, liquefied petroleum gas, or gas/oil (see Figure 5-17).

552.2 Oil-Burning Equipment

.21 General. An oil burner mechanically mixes fuel oil and air for combustion under controlled conditions. Ignition is accomplished by an electric spark, electric resistance wire, gas pilot flame, or oil pilot flame.

.22 Pressure-Atomizing Burners (Gun-Type). Pressure-atomizing (gun-type) burners are divided into two classes:

a. High-Pressure Mechanical Atomization. The high-pressure mechanical atomizing burner is characterized by an air tube, usually horizontal, with a pressurized oil delivery system centrally located in the tube (see Figure 5-18). The entire system is designed so that a spray of atomized oil is introduced at approximately 100 psig and mixed in the combustion chamber with the air stream emerging from the air tube. The oil is supplied to the burner by a fuel delivery unit serving as a pressure-flow regulating device as well as a pumping device. If electric ignition is used, a high-voltage transformer supplies approximately 10,000 volts to create an ignition arc across a pair of electrodes located above the nozzle. Where gas ignition is employed on a larger burner, a gas pilot is used with the firing rate governed by the size of the nozzle used. Multiple nozzles are used on some of the larger burners and variable-flow nozzles are used on others. A low fire start on a modulating burner with a variable flow nozzle is accomplished by supplying the oil at a reduced pressure. A low fire start on a multiple-nozzle burner is accomplished by permitting oil flow to only one or two of the nozzles.

b. Low-Pressure Mechanical Atomization. The low-pressure atomizing burner differs from the high-pressure-type mainly by its ability to supply a mixture of oil and primary air to the burner nozzle. The air meeting the

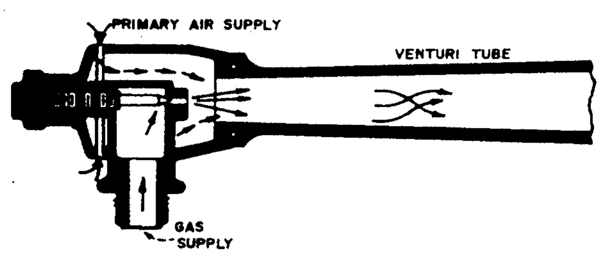


Figure 5-16
ATMOSPHERIC GAS BURNER

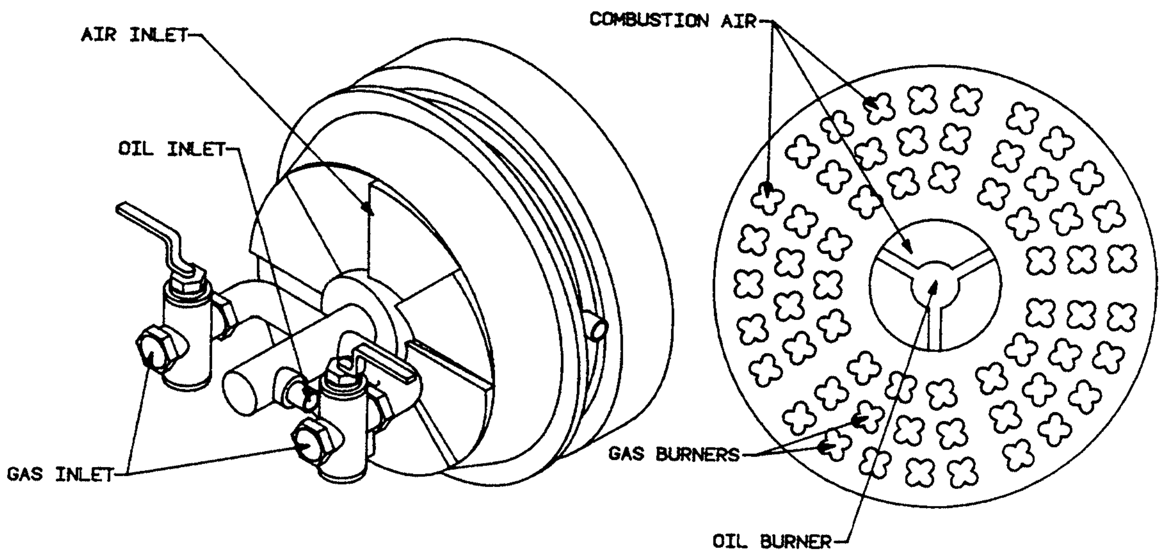


Figure 5-17

COMBINATION FUEL BURNERS

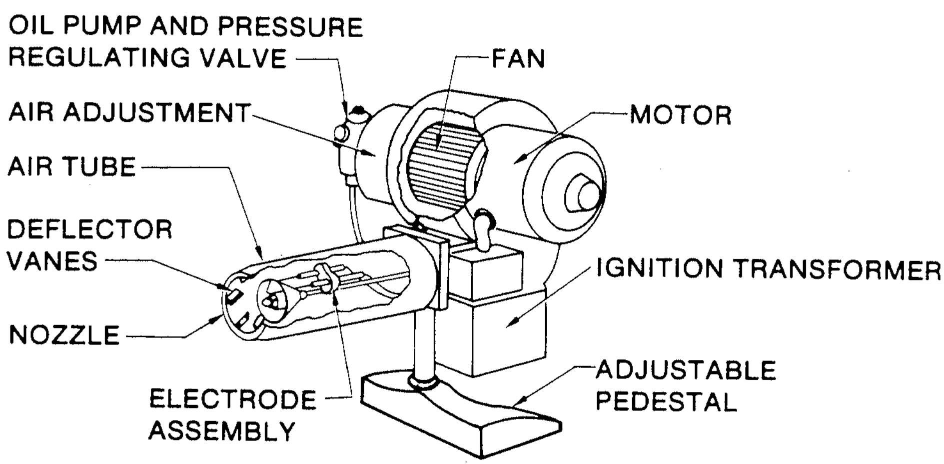


Figure 5-18

HIGH-PRESSURE ATOMIZING BURNER

mixture in the furnace is secondary air and provides for complete combustion. The air pressure before mixing and the pressure of the air/oil mixture vary with different makes of burners, but are in the low range of 1 to 15 psig for air and 2 to 7 psig for the air/oil mixture. Capacity of the burners is varied by making pump stroke or orifice changes on the oil pumps.

.23 **Steam-Atomizing Burners.** Steam-atomizing burners use steam to atomize heavy grade fuel oil. The steam is usually supplied by the boiler being operated.

.24 **Air-Atomizing Burners.** In this burner, the compressed air or steam is the atomizing medium. An air compressor is usually provided as part of the burner, but air may be supplied from another source.

.25 **Horizontal Rotary-Cup Burner.** The horizontal rotary-cup burner (see Figure 5-19) utilizes the principle of centrifugal atomization. The oil is

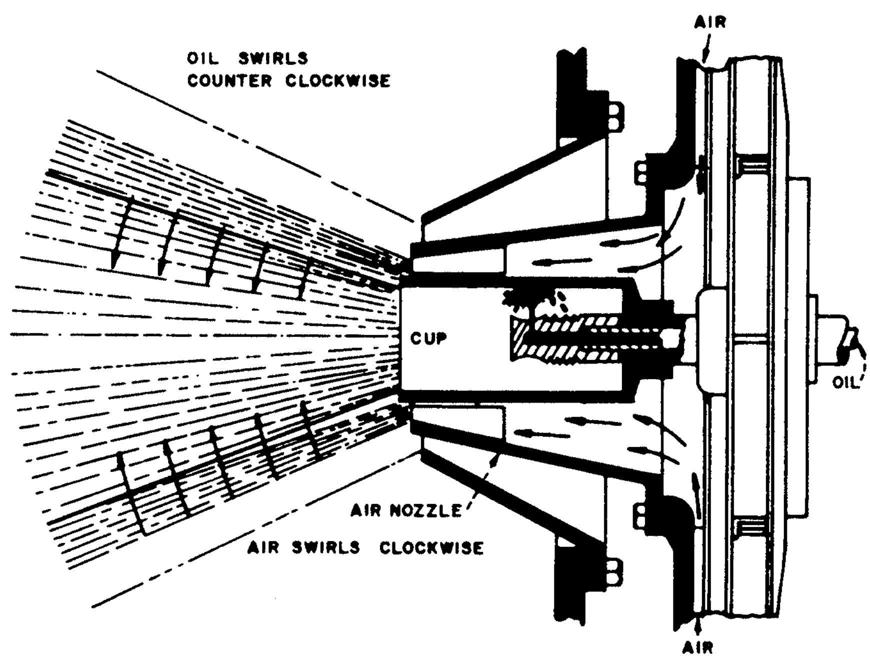


Figure 5-19
HORIZONTAL ROTARY-CUP FUEL OIL BURNER

prepared for combustion by centrifugal force. It spins off a cup that is rotating at high speed into an airstream that breaks up the oil into a spray. Modulated firing may be provided on these burners. This type of burner is primarily used with heavy oils, as it is harder to control fire when lighter oils are used.

552.3 Natural Gas Burners

.31 **General.** Natural gas is a clean-burning fuel, is easy to control from minimum to maximum usage, gives a constant heat, and is easy to mix with air to obtain good combustion.

.32 **Natural Gas Piping and Controls.** Due to the danger of leakage, natural gas controls and piping arrangements must meet the requirements of Underwriters' Laboratories (UL), Associated Factory Mutual Fire Insurance Companies (FM), and Industrial Risk Insurers (IRI, formerly FIA). All state and local codes must be met or exceeded when remodeling or installing equipment. Required controls vary according to size of boiler anburner, but all gas-supply controls must ensure that positive shutoff will occur when the burner cycles off. The standard pilot operated, diaphragm-type, gas regulator valve which is widely used does not close with enough force to ensure a positive shutoff. Gas explosions have occurred as a result of failure of the valve to close tightly. A motorized gassafety valvis now standard equipment on new installations. This valve is sometimes referred to as a dead-fall safety valve due to its instant closing action. The entire gas piping system is checked by compressed air at three times the normal gas pressure it will carry. Gas-pressure regulatorare required on all gas burners to maintain maximum pressure to the burner. Burner pressure isusually expressed in ounces or inches of water; all burners have an operating range which must be maintained. Required pressure for maximum fire is the highest pressure that should be on the system.

.33 **Atmospheric Burners.** The older firebox boilers are usually equipped with natural-draft burners. These are either upshot burners where the burners are installed on the floor, and the gas leaves the burners in a vertical direction, or inshot burners where the burners are mounted outside the firebox at the front of the and the gas leaves the burners in a horizontal direction, shooting into the firebox. Both types are atmospheric-injection burners similar to the type used in kitchen gas stoves. They require both primary and secondary air for proper combustion. Both air requirements are critical, as is the distribution of the secondary air. The burners have both minimum and maximum gas-pressure limits and the burners must be operated within these limits. Too much gas pressure will result in poor combustion, and not enough pressure will result in the gas burning inside the burner. The burners are usually cast-iron or steel and are not designed to withstand the heat of a direct flame. They will either crack open or warp and must be replaced. The air supply is regulated by air dampers, and the damper linkage is connected to the gas-regulator valve by a lever and chain. As the gas-regulator valve opens or closes, the linkage opens or closes the air dampers. The gas-regulator valve may be a two-position valve, either open or shut, or it may be a modulating-type valve that ranges anywhere between open and closed, depending on load demands. The two-position, or ON/OFF valve is the simplest type of valve, but the modulating-type is much preferred since it maintains a constant boiler pressure or temperature and is usually more economical than the ON/OFF-type.

552.4 Power Burners

.41 **Description.** Burners that pro-provide forced air for fuel mixing, flame direction control, and secondary air are referred to as power burners. The fan or blower supplying the air is combined with the burner to supply a mixture of gas and primary air leaving the burner tip. The secondary air is supplied in a pattern around the burner tip, and the final mixing and combustion takes place as the mixture travels through the firebox or furnace. This type of burner is usually operated by an automatic control system, where the pilot light is ignited and checked each time the burner is started and cuts off after the main burner starts operating.

.42 **Air Supply.** The air supply is automatically provided, in proportion to the gas supply, by a modulating motor that operates linkage connections to each supply. Adjustment of the air-to-fuel ratio is very critical and, when the burner is of the modulating-type, it is necessary to find a setting that provides the proper amount of air through the full modulation cycle. This requires checking the flue gas with proper instruments and adjusting the air volume while operating the burner from low- to high-fire positions.

.43 **Classification.** Burners are classified as either natural-draft or forced-draft. The natural-draft burner depends on the natural draft through the boiler and furnace pressure slightly below atmospheric to obtain combustion air. The forced-draft burner uses a blower to supply enough air to pressurize the furnace and force the combustion gases through the boiler.

552.5 Combination Gas and Oil Burners

Combination gas and oil burners use either fuel or both together. They are normally used in postal installations where natural gas is the main fuel, but must be backed up by a secondary or standby fuel. The standby fuel is usually No. 2 fuel oil that does not require preheating. The burner is a power burner combining a gas burner and an oil burner into one unit, using the same blower and control. The switchover is either manual or automatic. The oil burner may be either a gun-type, mechanical-pressure atomizing burner or an air-atomizing burner. The mechanical-pressure atomizing is normally specified on equipment for postal installations.

553 AUXILIARY EQUIPMENT

553.1 Induced-Draft Fan

Boilers installed on top floors of buildings or in locations where a tall stack is not feasible may be equipped with an induced-draft fan so the stack height can be reduced or the stack eliminated. The fan produces the required draft through the boiler when otherwise it would be created by the height of the stack. This type of fan might also be required to increase the boiler draft when converting from one fuel to another. The fan is usually mounted in a special housing that is part of the stack itself. The motor and drive are located outside the stack for protection from the high temperatures in the stack. The fan must be in operation before the burner comes on and must continue operating until after the burner is shut off. It is connected with the burner-control system to provide a boiler prepurge and postpurge to clear the boiler of all gases.

553.2 Barometric-Draft Regulator

This is a simple control item designed to maintain a predetermined airflow through a boiler. It is used on systems where the stack influences the draft through the boiler. The regulator is a simple sheet metal butterfly valve installed in the boiler breeching between the boiler and the smokestack. It has an arm with an adjustable weight which is positioned to determine the amount of draft in the boiler. If the stack draft increases, the weight on the regulator arm is overcome by the increased draft and the damper opens enough to pass the air needed for the increased draft. The draft through the boiler never exceeds the setting of the regulator.

560 GENERAL BOILER OPERATIONS AND LAYUP

561 GENERAL

When it is the responsibility of the USPS to either fire a boiler for the first time or fire a boiler which has been laid up for a period in excess of 24 months, the following procedures should be conducted by the installing contractor. However, local personnel must watch the procedure.

562 FIRING A NEW STEAM BOILER

When a boiler is to be fired for the first time:

a. The boiler must be checked internally and externally for material, tools, equipment, etc., which might have been left by laborers.

b. All firing equipment and controls must be checked as thoroughly as possible without actually starting a fire.

c. Fill the boiler to the normal water line, place all auxiliary equipment in operating position, and start the boiler on low fire. The boiler may have a high- or low-fire switch of some type, or the hand firing valve may be used to limit the burner to low fire.

WARNING

During burner lightoff, do not stand in front or back of boiler doors. In case of furnace explosion, the doors could be blown off or thrown open.

d. As soon as the burner is firing, check the condition of the fire, burner operation, boiler stack, and the venting system.

e. Check all safety controls and as many limit and operating controls as possible. Controls must be checked individually.

f. The operator must monitor the boiler while pressure is increased and all equipment, piping, etc., must be constantly observed during this period.

g. Before the system is placed in general service, all controls must be checked for proper operation and the pressure raised to check limit controls and the safety valve. This involves placing a jumper wire on operating and limit controls.

h. The entire steam and return system must be checked for proper operation and inspected for leaks or any evidence of potential trouble.

i. The system must be operated for 3 days at normal pressure. This will allow time for any oil, dirt, etc., in the system to be flushed back to the boiler.

j. The boiler must be shut down and the manhole cover removed for internal inspection. The water must be drained and the boiler checked for accumulation of oil and other foreign material on the waterside. If no evidence of oil or grease is found, the boiler can be returned to normal service by filling the boiler to the normal water line and heating the water until it is steaming. The boiler water must be treated with the prescribed boiler-water treatment, and then the boiler can be closed up and returned to service.

563 CLEANING A STEAM BOILER

After the boiler has operated for 3 days and has been checked (see Part 562), or if evidence of oil or grease is found inside the boiler shell, the following procedure must be followed:

a. Prepare a boilout compound by mixing caustic soda and trisodium phosphate in the proportions of 1 pound of each chemical per 50 gallons of boiler water.

WARNING

Caustic soda is harmful to eyes and skin. Do not permit the dry material or the concentrated solution to come in contact with skin or clothing. Use rubber gloves, apron, and goggles when handling caustic material. Always mix dry chemicals with water before putting them in the boiler.

b. Remove the manhole cover and add the boilout compound to the water in the boiler. Fire the boiler and bring the water to a slow boil, without producing excessive steam. Maintain the slow boil for at least 4 hours.

c. Shut down the boiler, slowly drain the boiler, and wash the interior with high-pressure water.

d. Refill the boiler, fire the boiler to boiling point so oxygen will be driven out of the water, add recommended boiler-water treatment, close the manhole opening, and return the boiler to service.

e. If the boiler is not clean after the first boiling-out period, the procedure may be repeated a second time following the same program.

564 FIRING A NEW HOT-WATER BOILER

The following procedure must be followed when placing a new hot-water boiler into operation:

a. The boiler must be checked internally and externally for material, tools, equipment, etc., which might have been left by laborers.

b. Check all firing equipment and controls as thoroughly as possible without actually starting a fire.

c. If the boiler shows evidence of excessive oil or grease, it can be cleaned separately (see Part 563. It is usually sufficient to clean the boiler and piping system at the same time by using trisodium phosphate as a cleaning agent. Partially fill the boiler with water, and the trisodium phosphate is added at the rate of one pound for each 50 gallons of water. Close up the boiler and fill and vent the entire system, except for the expansion tank. A pressure gauge at the highest point in the system will show a pressure of 2 to 3 psig when the system is filled and vented. At this point, consider the pressure in the boiler to be the minimum pressure for the system.

d. Start the circulating pump and check to see that water is circulating to all parts of the system. Fire the boiler on low fire and allow the water to slowly rise to operating temperature (between 180 and 210 °F). As soon as the burner is firing, check the flame condition, burner operation, boiler stack, and venting system.

WARNING

During actual lightoff of the burner, do not stand in front or back of boiler doors. In case of furnace explosion, the doors may be blown off or thrown open.

e. Check all safety controls and, as the temperature and pressure increase to operational values, check all operating and limit controls.

f. The operator must monitor the boiler while pressure is building, and all equipment, piping, etc., must be constantly observed during this period.

g. The system must be operated at normal temperature for 4 hours and then shut down and drained. The boiler must be opened and washed out with a high-pressure stream of water.

h. Close up the boiler, refill and vent the system, fire the boiler, and bring the system water up to normal operating temperature. Treat the system water as recommended, and make water tests to determine if proper conditions have been are obtained.

i. Before the system is placed in general service, all controls must be checked for proper operation, and the temperature and pressure must be raised above normal operation level to check the limit controls and safety-relief valve. All handhole and manhole covers must be tightened while the boiler is hot, but not under pressure.

j. After final adjustments are made on air-to-fuel ratio by checking the flue-gas CO_2 content, the system can be put in regular service or on standby.

565 LAYING UP A BOILER

565.1 General

Boilers should be laid up for storage when not in use. This may be during the summer months or for a full year. The type of boiler and the expected period of layup determines the method of layup used.

565.2 Steel Hot-Water Boilers

Unless the boiler is to remain out of service for over 1 year, nothing is done to the boiler. It must be left filled with treated water. If the boiler is to remain out of service for over 1 year, it must be laid up in the same manner as a steam boiler is laid up for a long period (see Section 565.33).

565.3 Cast-Iron Boilers

.31 General. All cast-iron boilers (steam and hot-water) are laid up in the same way. When the layup period is for less than 1 year, they are laid up using the wet method; when layup exceeds 1 year, they are laid up by the dry method.

.32 Wet Method. When a boiler is not needed for a period of 1 month to 1 year, it must be placed in storage or in layup to prevent corrosion of the boiler metal. The recommended method is the wet-type, where the boiler is removed from service, drained, and given an internal inspection and cleaning. All manhole and handhole covers must be removed for cleaning, and new gaskets must be installed when the covers are replaced. After the internal cleaning and inspection is completed, the boiler is filled with water to within a few inches of the top of the boiler. The boiler is fired with a low fire, and the water raised to boiling temperature and allowed to steam for 30 minutes to eliminate most of the oxygen in the water. The boiler water must be treated as recommended in Part 420 while the boiler is steaming. After the steaming period, the manhole cover can be replaced, and the boiler made tight. A vent valve should be opened, if possible, or the safety valve and the boiler-water level raised until water comes out the vent. The boiler should be checked at least once a month to determine if leakage into or out of the boiler has occurred. With all steam and return valves closed, any leakage out of the boiler will lower the pressure and the water level. A change in room temperature will also result in a change of pressure in the boiler. When the boiler is needed, the water is dropped to operating level and the boiler fired.

.33 Dry Method. When a boiler will not be used for a period exceeding 1 year, it should be laid up using the dry method. When one boiler is removed from service and the system is still in use, all valves connecting the boilers must be closed to provide a watertight seal. When a boiler is laid up dry, there must be no moisture inside the drum, or oxygen corrosion will result. When a boiler is laid up dry, the following tasks must be performed:

a. Drain the boiler while it is warm, remove all handhole and manhole covers, and clean the interior (waterside) of the boiler. Make a complete inspection of the waterside, checking for evidence of scale, corrosion, blisters, damaged metal, or loose tubes or bracing. Any needed repairs must be made as soon as possible. If the burner can be regulated, a small fire should be used to provide enough heat to dry out the moisture in the boiler.

CAUTION

The fire must be very small and not come in contact with any bare metal.

b. Replace the handhole covers. Place a tray of lime or other moisture-absorbing material, such as silica gel, inside the manhole opening. Seal the boiler. Check the boiler periodically and replace the absorbing material as necessary.

c. Regardless of the method used to lay up a boiler, the fireside is treated the same. The tubes must be cleaned when the boiler is removed from service. If humidity is high in the boiler room, the tubes must be coated with mineral oil to prevent corrosion. The fireside must be checked for loose or damaged firebrick or other insulating material. All metal, such as tubes, drum, bracing, etc., must be checked for evidence of leaking or overheating. The burner tips should be checked for evidence of overheating or clogged passages. Air should be allowed to circulate through the fireside to keep the metal dry. If moisture is a problem, the fireside should be closed up and a tray of moisture-absorbent material placed in the furnace.

566 RETURNING A BOILER TO SERVICE

566.1 From Wet Storage

Lower the water level to its normal operating level by using the boiler blowdown valve. The boiler is then ready to fire. The length of time a boiler is out of service determines the amount of checking and preparation necessary to ensure that the boiler is ready to fire. When the boiler has been out of service for a period of 3 months or longer, the procedure in Section 566.2 should be followed disregarding sections 566.2c and 566.2d concerning the boiler waterside.

566.2 From Dry Storage

Returning a boiler to service after a lengthy period in dry storage demands that a competent person familiar with the boiler and system supervise the preparation and actual firing of the boiler. Although most boilers and systems differ in some respects, the following procedure provides a guide that can be used on all boiler installations:

a. Review manufacturer's operating instructions handbook for startup of boiler and equipment.

b. Do not take anything for granted. Because a valve is supposed to be open does not mean that it is open. All items must be checked and verified.

c. Handhole and manhole openings should be checked and new gaskets installed. The interior of the drum should be checked and moistureabsorbent trays removed.

d. Reinstall all handhole covers and add water to the boiler until normal water level is reached.

e. Make sure combustion air to boiler room is unobstructed and boiler flue draft damper is open.

f. Check fuel supply and all equipment to determine that fuel is available at burner.

g. Check burner programmer with fuel off and with a clean flame detector.

h. Turn all switches to ON and set burner on low-fire position or use hand-firing cock to regulate fire to low-fire position.

i. Start burner and allow low fire to bring water temperature up slowly.

WARNING

Do not stand in front or back of boiler doors while boiler is being fired.

j. Bring water up to boiling temperature and allow to steam slowly for 30 minutes to drive off oxygen in the water. Shut down the burner, treat the boiler water, install the manhole cover, and open all steam valves to the system.

k. Check all valves on makeup water supply and on condensate-return system to ensure that they are open. Test condensate-return pumps for proper operation by physically raising floats or by energizing control circuits.

l. Fire boiler and raise pressure to normal level. Make sure pressure controller functions properly. While pressure is building, test all safety and operating controls for proper operation.

m. Lift safety valve by hand when pressure is normal. Check all boiler and burner auxiliaries. Observe flame condition and check flue gas for CO_2.

567 BOILER OPERATING TESTS AND INSPECTIONS

567.1 Responsibility

All testing and inspection requirements presented in this part are meant to be conducted by the boiler operator or the operator's supervisor. These are routine operational tests and inspections which do not take the place of required formal boiler inspections. Only qualified personnel may perform the tests. Record the tests on Form 4846, Low Pressure Heating Boiler Operating Log.

NOTE

Observe all safety precautions when conducting test.

567.2 Tests

.21 Try-Lever Test. Once a month during the heating season, the safety valve or safety-relief valve must be manually checked, (try lever test). This is done using a chain or rope long enough to be reached by a man standing on the floor and attached to the handle on the valve. The valve is opened for a period of at least 5 seconds and allowed to snap shut. If steam simmers from the valve or if water drips from the safety-relief valve, the valve should be quickly opened, allowed to snap shut and then checked to see if the valve seats itself with no leak. If either valve continues to leak, it must be repaired or replaced by an authorized representative of the manufacturer. A steam boiler should have a minimum of 5 psig steam pressure when the test is performed. A hot-water boiler should be at its normal operating temperature.

.22 **Pop Test.** The pop test determines the actual opening pressure and temperature of safety or safety-relief valves. It is performed by local personnel once a year and must be conducted just prior to the start of the heating season. For boilers that are operated 12 months a year, the test must be made when the boiler is shut down for cleaning and inspection. A pop test creates conditions that actually force the valve to operate as it would in an emergency. The steam-pressure controls must be adjusted orjumpered electrically to allow the pressure to reach the setting of the safety valve. The hot-water boiler pressure is raised by expansion of the water in the boiler. The expansion tank must be open to the boiler so that an air cushion is provided, otherwise the boiler could be damaged due to uncontrollable rising pressure. Except for large multistory buildings, most hot-water boilers have safety-relief valves set for 30 psig. For either hot-water or steam boiler, the system must be isolated from the boiler during the test. At least two persons knowledgeable in boiler testing must be present, and provision must be made to allow safe discharge of water and steam from the safety valves or safety-relief valves. The water discharge from safety-relief valves creates a considerable amount of steam, and this should be anticipated. If the safety valve or safety-relief valve does not pop at the set pressure, the test must be discontinued and the valve replaced or returned to the manufacturer for repair. The pressure gauge must be checked and calibrated before conducting the test.

567.3 Inspection

Although controls are referred to as operating, safety, or limit controls, they all perform a safety function. All controls should be visually checked daily, but once a month they must be inspected to determine that they are actually working. Such inspection involves creating conditions that allow the controls to operate. Although all boilers do not have identical controls, most have some type of the following:

a. Operating Controls. These controls maintain normal boiler operation and include the pressurestat, aquastat, fuel valves, modulating valves, level controllers, water-pressure regulator, etc.

b. Limit Controls. These controls maintain both high and low limits for steam or water pressure, water level, stack temperature, fuel pressure, and temperature, and include low-water level controller, pressure-limit stats, and temperature-limit stats (both high and low).

c. Safety Controls. These controls shut down the burner when a dangerous mechanical failure occurs and include flame failure, ignition failure, mechanical-draft failure, and circuit-failure controls.

d. Programmer System Controls. The burner should be stopped and started while watching the programmer control to ensure that the correct timing and sequence is carried out and that all phases operate correctly.

567.4 Preparing Boiler for Internal Inspection

The local office should prepare the boiler for internal inspection in the following manner:

a. Water must be drawn off and the boiler washed thoroughly.

b. Manhole and handhole plates, washout plugs, and inspection plugs in water-column connections must be removed. The boiler and combustion chamber must be thoroughly cooled and cleaned.

c. The furnace, combustion chamber, and fireside tubes must be cleaned.

d. All grates of internally fired boilers must be removed.

e. At each inspection, brickwork must be removed as required by the inspector in order to determine the condition of the boiler, headers, furnace, supports, or other parts.

f. The pressure gauge must be removed for testing.

g. Any leakage of steam or hot water into the boiler must be prevented by disconnecting the pipe or valve connecting the boiler to steam or another source of hot water.

h. The person responsible for preparing the boiler for inspection must be present at the inspection.

These instructions are further discussed in Section 10 of HBK MS-1, Operation and Maintenance of Real Property.

567.5 Boiler Logs

.51 **Low-Pressure.** Forms 4846 and 4846-A, Low-Pressure Heating Boiler Operating Logs, establish a standard for recording the operation of low-pressure boilers in order to improve safety, fuel economy, and maintenance. (See Exhibit 5-1 for an example of hot-water boiler logs, Form 4846-A, and Exhibit 5-2 for steam boiler logs, Form 4846.) Record each boiler operation on the proper form in accordance with instructions on the reverse of the form. These logs are not required for small domestic-type boilers with less than 400,000 Btu/hr input. However, all other maintenance operating and testing procedures prescribed herein, HBK MS-1, and HBK MS-49 must be followed for the small boilers.

.52 **High-Pressure Boilers.** The operation of high-pressure boilers (defined as steam boilers over 15 psig or hot-water boilers over 160 psig or 250 °F) requires a unique, more comprehensive log than Form 4846 or Form 4846-A. A special log must be developed and used at each location where high-pressure boilers are used.

.53 **Retention.** Completed logs will be retained for 3 years. After 3 years, one typical log for each month is retained indefinitely.

567.6 Boiler Malfunction

The headings on Form 4846 and Form 4846-A provide a place for the name(s) of the person or persons who are qualified to troubleshoot the boiler in case of emergency or malfunction. Since many boiler explosions are caused by persons manipulating controls in an effort to fire a boiler, only qualified personnel following the control manufacturer's instructions should attempt to correct control malfunctions.

567.7 Small Domestic-Type Boilers

Use of Form 4846 and Form 4846-A is not required on small, domestic-type boilers with less than 400,000 Btu/hr input. However, all other maintenance operating and testing procedures prescribed in this handbook, HBK MS-1, and HBK MS-49 must be followed.

568 PREVENTIVE MAINTENANCE

Each facility manager must verify that all preventive maintenance being performed on boiler and water heaters in facilities is in accordance with the preventive maintenance that is prescribed in Appendix 13-B, HBK MS-1, Operation and Maintenance of Real Property. Boilers must display Form 279A, Certificate of Inspection-Pressure Vessel, at all times.

NOTE

Particular attention is directed to the following preventive maintenance guides in Appendix 13-B, HBK MS-1:

A-5 Boilers, Oil-Fired

A-6 Boilers, Cast-Iron and Steel

A-7 Burners, Gas

A-8 Burners, Oil

570 OPERATION, MAINTENANCE, AND REPAIR —STEAM BOILERS

571 GENERAL

The boilers covered in this section are steel, fire-tube, low-pressure steam boilers. The information presented here is general in nature, but there should be no problem in relating this information to a specific piece or type of equipment. The manufacturer's handbook covering a particular boiler or system should be used in conjunction with this handbook to ensure that proper operation and maintenance procedures are followed.

572 STARTING A STEAM BOILER AND HEATING SYSTEM

572.1 Cleaning and Filling

.21 Inspection for Foreign Objects. Before starting a new boiler, an inspection must be made to ensure that no foreign matter such as tools, equipment, rags, etc., is left in the boiler.

.22 Checks Before Filling. Before putting water into a new boiler, to the extent that it is possible without lighting a fire in the empty boiler, make certain that the firing equipment is in operating condition. This is necessary because in order to drive off the dissolved gases that might otherwise corrode the boiler, raw water must be boiled (or heated to at least 180 °F promptly after it is introduced into the boiler.

.23 System Cleaning. Fill the boiler to the proper waterline and operate the boiler for a few days with steam in the entire system to bring the oil and dirt back from the system to the boiler. This is not necessary if the condensate is to be temporarily wasted to the sewer, in which case the system should be operated until the condensate runs clear.

.24 Boilout. The oils and greases hich accumulate in a new boiler can usually be washed out by following these procedures:

a. Fill the boiler to the normal water line.

b. Remove plug from tapping on highest point on the boiler. If no other opening is available, the safety valve may be removed; however, the valve must be handled with extreme care so as not to damage it.

c. Mix a boilout compound (caustic soda and trisodium phosphate in the proportions of 1 pound of each chemical per 50 gallons of water) with water and pour into the boiler through the prepared opening.

WARNING

Use care in handling these chemicals. Caustic soda is harmful to skin, clothing, and eyes. Do not permit either the dry material or the concentrated solution to come in contact with skin or clothing.

d. Replace the plug or the safety valves.

e. Start the firing equipment and check operating, limit, and safety controls. Review the manufacturer's recommendations for boiler and burner startup.

f. Boil the water for at least 5 hours.

g. Stop the firing equipment.

h. Using caution, drain the boiler to a location where hot water can safely be discharged.

i. Wash the boiler thoroughly, using a high-pressure water stream.

j. Fill the boiler to the normal water line.

k. Add boiler-water treatment compound as needed (see Chapter 4).

l. Promptly boil or heat the water to a temperature of 180 °F.

m. Put the boiler into service or on standby.

.25 **Second Boilout.** In some cases, this simple boilout may not remove all the oil and grease, and another boilout using a surface blowoff may be necessary. For this type of cleaning, proceed as follows:

a. Prepare the boiler for cleaning by running a temporary pipeline from the surface blowoff connection to an open drain or some other location where hot water may be safely discharged. If no such tapping is available, use the safety valve tapping, but run the pipe full size and in as short a length as possible. Do not install a valve or any other obstruction in this line. Handle the safety valve carefully and protect it against damage while it is out of the boiler.

b. Fill the boiler until the water reaches the top of the water gauge glass.

c. Add caustic soda and trisodium phosphate in the proportions of 1 pound of each chemical per 50 gallons of boiler water.

d. Start the firing equipment and operate sufficiently to boil the water without producing steam pressure.

e. Boil for about 5 hours.

f. Open the boiler feedpipe sufficiently to permit a steady trickle of water to run out the overflow pipe.

g. Continue this slow boiling and trickle of overflow for several hours until the water coming from the overflow is clear.

h. Stop the firing equipment.

i. Using caution, drain the boiler to a location where hot water can safely be discharged.

j. Remove covers and plugs from all washout openings and wash the waterside of the boiler thoroughly, using a high-pressure water stream.

k. Refill boiler until 1 inch of water shows in the gauge glass.

NOTE

If the water in the gauge glass does not appear to be clear, repeat steps (b) through (k) and boil out the boiler for a longer time.

l. Remove the temporary piping.

m. Add a charge of boiler-water treatment compound.

n. Close the boiler.

o. Replace the safety valve.

p. Put the boiler into service or standby.

572.2 Starting After Layup (Single Boiler Installation)

When starting a boiler after layup, proceed as follows:

a. Review the manufacturer's recommendations for startup of burner and boiler.

b. Set the control switch in the OFF position.

c. Make sure the path of fresh air to the boiler room is unobstructed.

d. Check the availability of fuel.

e. Check the water level in the gauge glass. Make sure the gauge-glass valves are open.

f. Use try cocks, if provided, to doublecheck the water level.

g. Vent the combustion chamber to remove unburned gases.

h. Clean the fire scanner glass, if provided.

i. Open the main steam shutoff valve.

j. Open the cold-water supply valve to the water feeder, if provided. Open the suction and discharge valves on vacuum or condensate pumps and set electrical switches for desired operation. Vent the boiler to remove air when necessary.

k. Check the operating pressure setting of the boiler.

l. If provided, check the manual reset on the low-water fuel cutoff and high-limit pressure controls to determine if they are properly set.

m. Open the manual fuel-oil supply or manual gas valve.

n. Turn on the circuit breaker or fused disconnect switch.

o. Turn on all boiler emergency switches.

p. Turn on the boiler control starting switch.

WARNING

Do not stand in front of boiler access or cleanout doors. This is a precautionary measure since a combustion explosion could occur.

q. Slowly raise the pressure and temperature. Stand by the boiler until it reaches the established cutout point to ensure that the operating control shuts off the burner.

r. During the pressure buildup period, walk around the boiler frequently to observe that all associated equipment and piping is functioning properly. Check for proper over-the-fire draft.

s. Immediately after the burner shuts off, inspect the water column and open each try cock (if provided) individually to determine true water level.

t. Enter the following in the log book:

(1) Date and time of startup

(2) Any irregularities observed and corrective action taken

(3) Time when controls shut off burner at established pressure, tests performed, etc.

(4) Signature of operator

u. Check the safety valve for evidence of simmering. Perform a try-lever test (see Section 567.2).

572.3 Abnormal Conditions

If any abnormal conditions occur during lightoff or pressure buildup, immediately open the emergency switch. Do not attempt to restart unit until difficulties have been identified and corrected.

572.4 Condensation

Following a cold start, condensation (sweating) may occur in a gas-fired boiler to such an extent that it appears the boiler is leaking. This condensation should stop after the boiler is hot.

572.5 Cutting in an Additional Boiler

When placing a boiler on the line with other boilers already in service, start the boiler using the procedures in Section 572.2; however, keep the supply stop valve and the return stop valve closed. If one is provided, open the drain valve located between the stop valve at the boiler outlet and the steam main. When the pressure within the boiler is approximately the same as the pressure in the steam main, open the stop valve very slightly. If there is no unusual disturbance, such as noise, vibration, etc., continue to open the valve slowly until it is fully open. Then open the valve in the return line.

NOTE

When the stop valve at the boiler outlet is closed, the stop valve in the return line of that boiler must also be closed.

573 OPERATION

573.1 Water Level

.11 **Checks and Tests.** Check the water gauge regularly, determining by trial the required frequency. The check should be made when there is steam pressure in the boiler. Close the lower gauge-glass valve, then open the drain cock located on the bottom of the valve and blow the glass clear. Close the drain cock and open the lower gauge-glass valve. Water should return to the gauge glass immediately. If water return is sluggish, leave the lower gauge-glass valve open and close the upper gauge-glass valve. Then open the drain cock and allow water to flow until it runs clear.

.12 **Leaks.** Close the drain valve and repeat the test described in Section 573.11 with the lower gauge-glass valve closed. If leaks appear around the water gauge glass or fittings, correct the leaks at once. Steam leaks may result in a false water line and may also damage the fittings.

.13 **Blowdown.** If water disappears from the water gauge glass, blow down the gauge glass to see if water appears. If it does not appear, stop the fuel supply immediately. Do not turn on the water feed line. Do not open the safety valve. Let the boiler cool until the crown sheet is below 120 °F. Then add 1 inch of water in the gauge glass. Do not put the boiler back into service until the condition responsible for the loss of water has been identified and corrected.

573.2 Steaming Pressure

.21 **Set Pressure.** A common danger in steam-heating boilers comes from the failure of the safety valve(s) to open at the set pressure. This is usually due to the buildup of a corrosive deposit between the disk and the seat of the safety valve which is caused by a light leakage or weeping of the valve.

.22 **Pressure Differential.** The snap-action opening of a safety valve occurs when the boiler steam pressure on the underside of the valve disk overcomes the closing force of the valve spring. As the force of the steam pressure approaches the counteracting force of the spring, the valve tends to leak slightly and, if this condition is permitted to exist, the safety valve can stick or freeze. For this reason, the pressure differential between the safety valve set pressure and the boiler operating pressure must be at least 5 psi; i.e., the boiler operating pressure must not exceed 10 psig. If, however, the boiler operating pressure is greater than 10 psig, it should not exceed 15 psig minus the blowdown pressure of the safety valve. This pressure differential is also required to ensure that the safety valve will seat tightly both after popping and when the boiler pressure is reduced to normal operating pressure.

NOTE

Periodic testing of safety valves must be carried out in accordance with Part 567.

573.3 Blowdown

Where low-pressure steam boilers are used solely for heating and where practically all of the condensate is returned to the boiler, blow down only as often as concentration of solids require. Boilers used for process steam that require high makeup must be blown down as required to maintain chemical concentrates at the desired level and to remove precipitated sediments. Boilers equipped with slow-opening blowoff valves and a quick-opening blowoff cock must have the levers or cocks opened first. The slow-opening valve must then be gradually opened and closed. When the slow-opening valve has been shut tightly, close the lever valve or cock.

CAUTION

Do not open the slow-opening blowoff valve first and then pump the lever-action blowoff cock open and closed. The water hammer is apt to break the valve bodies or pipe fittings.

573.4 Rust

If rust appears in the water gauge glass, it indicates corrosion and must not be ignored. Check the boiler water to ensure that the water-treatment compound is at proper strength and make sure the boiler is not using considerable quantities of makeup water. Check the return line and other parts of the system for evidence of corrosion.

573.5 Waterline Fluctuation

A wide fluctuation of water line may indicate that the boiler is foaming or priming. This may be due to a very high rate of steam, especially in low- h pressure boilers, or due to the water level in the boiler being carried too high. Foaming may also be caused by dirt or oil in the boiler water. Foaming can sometimes be cured by blowing the boiler down, draining 2 or 3 inches of water, and then refilling the boiler a few times. If foaming persists, it may be necessary to take the boiler out of service, drain, and wash out thoroughly as described in Section 572.1. The boiler is then refilled and put back into service.

573.6 Abnormal Water Loss

The requirement of large amounts of manually fed makeup indicates abnormal water loss. An immediate investigation must be made to determine the cause. Boilers operated with automatic water feeders requiring an increase in water-treatment must be immediately investigated for cause of loss of water. Proper repair or replacement of parts must be made at once. If the operator cannot determine the cause of the water loss, a competent contractor should be contacted.

573.7 Makeup Water

When makeup water is needed and neither the boiler nor the condensate tank is equipped with an automatic water feeder, manually add water to the steam boiler following these procedures:

a. Use every practical means for excluding oxygen from the boiler water. One source of oxygen is makeup water; therefore, hold makeup to a minimum. If the boiler loses more than 3 inches of water per month, this indicates a probable leak in some part of the system. The leak must be found and corrected.

b. If the system includes a pump for returning condensate or adding feedwater, be certain that the air vent at the receiver is operating properly.

c. If large quantities of feedwater are required, de-aerating equipment is recommended to remove dissolved gases, thereby reducing oxygen corrosion.

573.8 Low-Water Cutoff

.81 Inspection. Check the operation of the low-water cutoff, pump control, and the water feeder (if one is installed). Follow the manufacturer's blowdown instructions on the tag or plate attached to each control.

.82 Tests. Periodically, the low-water cutoff may be tested under actual operating conditions. With the burner operating and the boiler steaming at the proper water level, close all the valves in the feedwater and condensate-return lines so the boiler will not receive any replacement water. Then carefully observe the water line to determine where the cutoff switch stops the burner in relation to the lowest permissible water line established by the boiler manufacturer. If the burner cutoff level is not 1 inch above the lowest permissible water line, the low-water cutoff should be moved to the proper elevation in a new installation, or it should be serviced, repaired, or replaced in an existing installation.

574 REMOVAL OF STEAM BOILER FROM SERVICE

574.1 Procedure

To remove a steam boiler from service at the end of the heating season or for repairs, proceed as follows:

a. While maintaining boiler-water temperature (180 to 200 °F), drain off the water from the bottom drain until it runs clear.

b. Refill water to the top of the gauge glass and add sufficient water-treatment compound to bring the treatment up to strength.

c. After all the dissolved gases are released (approximately 1 hour), shut down the firing equipment by disconnecting the main switch.

NOTE

For treatment of laid up boilers, see Chapter 4.

574.2 Cleaning

When the boiler is cool, thoroughly clean the tubes and other fireside heating surfaces. Scrape the heating surfaces down to clean metal. Clean the smokeboxes and other areas where soot or scale may accumulate. Soot is not corrosive when it is perfectly dry, but can be very corrosive when damp. For this reason, all soot must be removed from a boiler at the beginning of the nonoperating season or any extended nonfiring period.

574.3 Corrosion Protection

Swab the fireside heating surfaces with neutral mineral oil to protect against corrosion. If the boiler room is damp, place a tray of calcium chloride or unslaked lime in the combustion chamber and replace the chemical when it becomes mushy.

574.4 Water Level

Drain a steam boiler back to the normal water level before putting the boiler back in service.

574.5 Periodic Checks

Check the boiler occasionally when it is idle to ensure it is not corroded.

575 MAINTENANCE

575.1 Cleaning

Clean the boiler tubes, smokeboxes, and other heating surfaces as needed. The frequency of the cleaning is best determined by trial, but must be done at least annually. A general prediction of the frequency of cleaning applicable to all boilers cannot be made.

575.2 Draining

A clean, properly maintained steam-heating boiler should be drained if there is a possibility of freezing, if the boiler has accumulated a considerable amount of sludge or dirt on the waterside, or if it is necessary to make repairs to the waterside. Very little sludge should accumulate in a boiler where little makeup water is added and where appropriate water treatment is maintained at the proper strength.

575.3 Antifreeze

Antifreeze solutions, when used in heating systems, should be tested from year to year as recommended by the antifreeze manufacturer. Antifreeze solutions should not be circulated through the boiler. The antifreeze solution should be heated in an indirect heat exchanger.

575.4 Fireside Corrosion

.41 **General.** The causes of waterside corrosion and procedures to remove it are discussed in Section 422.3.

Boilers also corrode on the fireside. Some fuels contain substances that cause fireside corrosion. Sulphur, vanadium, and sodium are among the materials which may contribute to this problem.

.42 **Sulphur.** Deposits of sulphur compounds may cause fireside corrosion. The probability of trouble from this source depends on the amount of sulphur in the fuel and on the care used in cleaning the fireside heating surfaces. This is particularly true when preparing a boiler for a period of idleness. Preventing fireside corrosion also depends on keeping the boiler heating surfaces dry when a boiler is out of service.

.43 **Vanadium.** Deposits of vanadium or vanadium and sodium compound also cause fireside corrosion. These compounds may be corrosive during the season when boilers are in service.

.44 **Cleaning and Inspection.** The person responsible for boiler maintenance should be certain that the fireside surfaces of the boilers are thoroughly cleaned at the end of the firing season. If signs of abnormal corrosion are discovered, a reputable contractor should be engaged.

575.5 Safety Valves

Safety valves on steam boilers must be tested for proper operation as outlined in with Part 567. ASME-rated safety valves must be installed on the boiler. When replacement is necessary, use only ASME-rated valves of the required capacity.

575.6 Burner Maintenance

.61 **Oil Burners.** Oil burners require periodic maintenance to keep the nozzle and other parts clean. Check and clean the oil-line strainers. Inspect and check the nozzle and check the oil level in the gear cases. Check and clean filters, air-intake screens, blowers, and air passages. Check all linkages and belts, adjust as required, and lubricate in accordance with the manufacturer's recommendations. Check the pilot burners and ignition equipment for proper flame adjustment and performance.

.62 **Gas Burners.** Check gas burners for dirt, lint, or foreign matter. Ensure parts, gas passages, and air passages are free of obstructions. Linkages, belts, and moving parts on power burners should be checked for proper adjustment. On combination oil and gas burners, after prolonged periods of oil firing, the gas outlets may become caked with carbon residues from unburned fuel oil and will require cleaning. Any required lubrication must be in accordance with the manufacturer's recommendations. Check the pilot burners and ignition equipment for proper flame adjustment and performance.

575.7 Low-Water Fuel Cutoff and Water-Feeder Maintenance

Qualified personnel must annually dismantle low-water fuel cutoffs and water feeders to the extent necessary to ensure freedom from obstructions and proper functioning of the working parts. Inspect connecting lines to the boiler for accumulation of mud, scale, etc., and clean as required. Examine all visible wiring for brittle or worn insulation and make sure electrical contacts are clean and functioning properly. Give special attention to solder joints on the bellows and float if this type of control is used. Check the float for evidence of collapse, and check the mercury bulb (where applicable) for mercury separation or discoloration. Do not attempt to repair mechanisms in the field. Complete replacement mechanisms, including necessary gaskets and installation instructions, are available from the manufacturer.

575.8 Flame Safeguard Maintenance

.81 **Thermal-Type Detection Device.** Check the device for electrical continuity and satisfactory current generation in accordance with the manufacturer's instructions.

.82 **Electronic-Type Detection Device.** Annually replace the vacuum tubes or transistors annually with the type recommended by the manufacturer. Check operation of the unit in accordance with manufacturer's instructions and examine for damaged or worn parts. Do not attempt to repair these units in the field. Replacement assemblies are available from the manufacturer on an exchange basis.

575.9 Limit-Control Maintenance

Maintenance on pressure-limiting controls is generally confined to a visual inspection of the device for evidence of wear, corrosion, etc. If the control is a mercury bulb-type, check for mercury separation and discoloration of the bulb. If the control is defective, replace it. Do not attempt to make field repairs.

576 CAST-IRON BOILER AND STEEL BOILER MAINTENANCE

576.1 Cast-Iron Boiler Maintenance

.11 **Heating Surfaces.** Check the firebox gas passages and breeching for soot accumulation. If required, use a wire brush and vacuum cleaner to remove the soot or other dirt accumulations.

.12 **Internal Surfaces.** If there is considerable foreign matter in the boiler water, the boiler must be allowed to cool, then drained and thoroughly flushed out. Remove the blowdown valves and plugs from the front and rear sections and with a highpressure water stream, wash through these openings. This will normally remove any sludge or loose scale. If hard scale has formed on the internal surfaces, the boiler must be cleaned by chemical means, as prescribed by a qualified water-treatment specialist.

576.2 Steel Boiler Maintenance

.21 **Heating Surfaces.** Remove all accumulations of soot, carbon, and dirt from the fireside of the boiler. Use a flue brush to clean the tubes. Clean the breeching and stack as required. Inspect the refractory and make any necessary repairs.

.22 **Internal Surfaces.** Blow down the boiler as required. If water does not run clear, the boiler must be cleaned. After the boiler is allowed to cool, clean it by venting and draining the boiler, removing all manhole and handhole covers, and washing the inside of the boiler with a high-pressure water stream. Loosen any solidified sludge, scale, etc., with a hand scraper. Start at the top of the boiler and work down. Flush thoroughly after cleaning. Where access is limited or where scale buildup is difficult to remove, it may be necessary to clean the boiler chemically, as prescribed by a qualified water-treatment specialist.

576.3 Tubes

If one tube in a boiler develops a leak due to corrosion, it is likely that other tubes are corroded. Have the boiler examined by a capable and experienced inspector before ordering any replacement tubes. If all the tubes will need replacement soon, it is preferable and less expensive to have all the work done at one time.

NOTE

Do not use sealant in boilers.

576.4 Periodic Tests

.41 **Daily.** Boilers in service require daily testing. Observe operating pressures, water level, and general conditions. Determine and correct the cause of any unusual noise or condition.

.42 Weekly. The following tests should be made weekly on boilers in service:

a. Test the low-water fuel cutoff and/or water feeder. Blow down the boiler if considerable makeup is used.

b. Test the water column or gauge glass.

c. Observe the flame; if the flame is smoky or if the burner starts with a puff, correct. For oil burner, observe the flame daily.

d. Check the fuel supply (oil only).

e. Observe the operation of condensate or vacuum pump.

.43 Monthly. The following tests should be made monthly on boilers in service:

a. Test the flame-detection devices.

b. Test the limit controls.

c. Test the operating controls.

d. Blow down sludge, if required.

e. Check the boiler room floor drains.

f. Inspect the fuel supply systems in the boiler room.

g. Check the condition of the heating surfaces. Inspect preheated oil burners twice a month.

h. Perform a try-lever test on the safety valve.

.44 Annually. The following tests should be made annually:

a. After thorough cleaning, inspect the interior and exterior.

b. Carry out routine burner maintenance (see Section 575.6).

c. Carry out routine maintenance of condensate- or vacuum- return equipment.

d. Carry out routine maintenance of all combustion-control equipment.

e. Perform combustion and draft tests (see Part 593).

f. Perform safety or safety-relief valve pop test (see Section 575.5).

g. Make a slow drain test of low-water cutoff.

h. Inspect the gas piping for proper support and tightness.

i. Inspect the boiler room ventilation louvers and intake.

NOTE

A copy of this schedule in checklist format is contained in Appendix C, Exhibit 5-4.

.45 Internal Inspection. When practical, use a flashlight rather than an extension light for internal inspections. If an extension light is taken into a boiler, ensure that the cord is rugged, in good condition, and properly grounded. It should be equipped with a vapor-tight globe, substantial guard, and nonconducting holder and handle.

576.5 Steam-Pressure Gauge

A steam-pressure gauge should never be used without a water trap or siphon tube, sometimes referred to as a pigtail, to protect the gauge from the high temperature of the steam. The steam gauge needle should return to zero when the system is off or when the gauge is removed. All pressure gauges must be equipped with a gauge cock valve so the gauges can be removed while the system is under pressure. The gauge cock is also used to damp out any fluctuation in the pressure to prevent the gauge needle from jumping or moving. Rapid movement of the needle will result in a wearing action on the pinion gear in the gauge and will render the gauge useless. Steam pressure must never be carried higher than necessary; a constant pressure should be maintained, if possible. A low-pressure steam boiler has safety valves that open at 15 psig. The normal operating pressure should never be over 10 psig steam pressure.

576.6 Maintenance of Condensate-Return Systems

Inspect and clean the strainer upstream from of the pump. Drain and flush the condensate tank. Check pump packing, float switches, and vacuum switches, as applicable. For detailed instructions, refer to manufacturer's maintenance data and recommendations.

577 BOILER REPAIRS

577.1 Safety

Never attempt to repair a boiler while it is in service or under pressure, except with the approval and under the supervision of an authorized boiler inspector or responsible engineer. Take every precaution necessary to ensure the safety of employees working in the boiler room and particularly of those working inside the steam space or in the combustion chamber of the boiler. Pull the main burner switch,lock it out, and tag it with Form 4707, Out of Order. Swing the burner out of place, if possible. Close and lock valves, etc. Someone must always be standing by outside the boiler when anyone works inside the boiler.

577.2 Notification

When repair work is required, notify the authorized boiler and pressure vessel inspector and be guided by the inspector's recommendations.

577.3 Welding Requirements

All repair work should be done by experienced boiler mechanics. All welding should be done by qualified welders using proper procedures.

578 TESTS AND INSPECTIONS

578.1 Purpose

Periodic inspections ensure protection against loss of or damage to the pressure vessel because of corrosion, pitting, etc. These inspections also provide protection against unsafe operating conditions possibly caused by changes in piping or controls or lack of testing of safety devices. Inspections must be thorough and complete. So that all important elements may be checked, the following recommended directions and instructions for such inspections are given.

NOTE

> The tests recommended for burner efficiency, combustion safeguards, safety controls, operating controls, limit controls, safety valves, and safety-relief valves are included in Part 567.

578.2 Preparing Boilers for Inspection

Whenever an inspection is scheduled, all steam-heating boilers must be prepared for it. Prepare the boiler for an internal inspection and prepare for and apply the hydrostatic test on the date specified in the presence of a duly qualified inspector.

Before inspection, every accessible part of a boiler must be opened and properly prepared for examination, both internally and externally. In cooling down a boiler for inspection or repairs, the water must not be withdrawn until the setting is sufficiently cooled. This avoids damage to the boiler. When possible, the boiler should be allowed to cool down naturally.

Prepare a boiler for internal inspection in the following manner:

a. Water must be drained and the boiler washed thoroughly.

b. All manhole and handhole plates, washout plugs, and water-column connections must be removed and the furnace and combustion chambers thoroughly cooled and cleaned.

c. All grates in internally fired boilers should be removed.

d. Brickwork should be removed as required by the inspector in order to determine the condition of the furnace, supports, or other parts.

e. Any leakage of steam or hot water into the boiler should be cut off by disconnecting the pipe or valve at the most convenient point.

It is not necessary to remove insulation material, masonry, or fixed parts of the boiler unless defects or deterioration are suspected. Where there is moisture or vapor showing through the covering, the covering must be removed at once and a complete investigation made to find the cause. Every effort must be made to discover the true condition, even if it means drilling holes or cutting away parts.

578.3 Inspection

.31 **Procedure.** The inspector should get as close as possible to the parts of the boiler in order to obtain the best vision of the surface. The inspector should use a good artificial light, if natural light is inadequate. Whenever the inspector deems it necessary to test boiler apparatus, controls, etc., these tests should be made by a plant operator in the presence of the inspector unless otherwise ordered.

.32 **Corrosion.** Types of harmful materials are as follows:

a. Surfaces. The inspector should examine all surfaces of the exposed metal inside the boiler to detect any corrosion caused by treatment, scale solvents, oil, or other substances which may have entered the boiler. Any evidence of oil should be noted carefully, since even a small amount is dangerous. Immediate steps must be taken to prevent the entrance of any more oil into the boiler. Oil or scale on plates above the boiler fire is particularly dangerous, often causing sufficient weakening to bag or rupture the plates.

b. Seams and Joints. Corrosion along or immediately adjacent to a seam is more serious than a similar amount of corrosion in the solid plate away from the seams. Grooving and cracks along longitudinal seams are especially significant, since they are likely to occur when the material is highly stressed. Severe corrosion is likely to occur at points where the circulation of water is poor; such places should be examined very carefully. For the purpose of estimating the effect of corrosion or other defects upon the strength of a shell, a comparison must be made with the efficiency of the longitudinal joint of the same boiler, the strength of which is usually less than that of the solid sheet.

.33 Stays, Manholes, and Openings. Inspection of stays, manholes, and openings should be as follows:

a. Stays. All stays, diagonal or through, should be examined to see if they are in even tension. All fastened ends should be examined to note if cracks exist where the plate is punched or drilled. If stays are not found in proper tension, then proper adjustment must be made.

b. Manholes and Openings. The manhole(s) and other reinforcing plates, as well as nozzles and other connections flanged or screwed into the boiler, must be examined both internally and externally to determine if they are cracked or deformed. Whenever possible, observation should be made from the inside of the boiler to check the thoroughness with which the pipe connections are made to the boiler. All openings to external attachments, such as watercolumn connections, openings in dry pipes, and openings to safety valves, should be examined to ensure their freedom from obstructions.

.34 Fire Surfaces, Lap Joints, and Tubes. Inspection of fire surfaces, lap joints, and tubes should be as follows:

a. Fire Surfaces. Particular atten-attention should be given to any plate or tube surface exposed to fire. The inspector should observe whether or not any part of the boiler has become deformed (bulging or blistering) during operation. If bulges or blisters are large enough to seriously weaken the plate or tube, especially if water is leaking from such a defect, the boiler should be removed from service until the defective part or parts have been repaired. Carefully watch for leakage from any part of the boiler structure, particularly in the vicinity of seams and tube ends. Firetubes sometimes blister but rarely collapse; the inspector should examine the tubes for blistering and replace them, if necessary.

b. Lap Joints. Lap-joint boilers are apt to crack where the plates lap in the longitudinal or straight seam. If there is any sign of leakage or other distress at this joint, it must be investigated thoroughly to determine if cracks exist in the seam. Any cracks noted in shell plates are usually dangerous.

CAUTION

Staybolts should be tested by tapping one end of each bolt with a hammer. When possible, holding a hammer or other heavy tool at the opposite end makes the test more effective. A dull sound may indicate deterioration of the staybolt.

c. Tubes. Tubes in horizontal fire-tube boilers deteriorate more rapidly at the ends near the fire. These ends should be carefully tapped on their outer surface with a light hammer on their outer surface to determine if there has been a serious reduction in thickness. Without water cooling, the tubes of vertical tubular boilers are more susceptible to deterioration at the upper ends when exposed to fire or heat. They should be inspected by reaching as far as possible through the handholes (if any) as well as inspected at the ends. Tube surfaces should be carefully examined to detect bulges, cracks, or any evidence of defective welds. If exposed to a strong draft, tubes may become thinned by the erosion produced by the impingement of particles of fuel and ash. A leak from any tube frequently causes serious corrosion on a number of neighboring tubes. The ligaments between tube holes in the heads of all fire-tube boilers and in shells of water-tube boilers must be examined. If any leakage is noted, broken ligaments are probably the reason.

.35 Pipes. Inspection of pipes should be as follows:

a. The steam and water pipes, including connections to the water columns, must be examined for leaks. If any are found, it must be determined whether they are the result of excess strain due to expansion, contraction, or some other cause. The general arrangement of the piping in regard to provisions for expansion and drainage, as well as adequate support at the proper points, should be carefully noted. The location of the various stop valves should be observed to see that water will not accumulate when the valves are closed and cause water-hammer action.

b. The arrangement of connections between individual boilers and the main steam header should be especially noted to ensure that any change in position of the boiler (due to settling or other causes) has not placed an undue strain on the piping.

c. Determine if all pipe connections to the boiler have the proper strength in their fastenings, whether tapped into or welded to the boiler shell. The inspector should ensure that there is proper provision for the expansion and contraction of the piping and that there is no undue vibration that could damage parts (this includes all steam and water pipes). Special attention must be given to the blowoff pipes and their connections and fittings, because their expansion and contraction due to rapid changes in temperature and water-hammer action cause a great strain upon the entire blowoff system. The freedom of the blowoff and drain connections on each boiler should be tested, whenever possible, by opening the valve for a few seconds, at which time it can be determined whether or not there is excessive vibration.

d. Carefully inspect the piping to the water column to ensure there is no chance of water accumulating in the pipe that forms the steam connection to the water column. The steam pipe preferably should drain toward the water column. The water pipe connection to the water column must drain toward the boiler. Check the position of the water column relative to the fire surfaces of the boiler to determine whether or not the column is placed in accordance with code requirements. Examine all attachments to determine their operating condition.

e. If the examination is performed while steam is in the boiler, observe the water column and gauge glass to see that the connections to the boiler are free, as shown by the action of the water in the glass. The water columns and gauge glasses should be blown down on each boiler to definitely determine the freedom of the connections to the boilers, as well as to see that the blowoff piping from the columns and gauge glasses are free. The gauge glasses should be examined to see that they are clean and properly located to permit ready observation. The freedom of the gauge glass should be determined by test.

.36 Low-Water Cutoff and Water Feeder. Inspection of low-water cutoffs and water feeders should be as follows:

a. All automatically fired steam or vapor boilers must be equipped with an automatic low-water fuel cutoff or water-feeding device. The device must be so constructed that the water-inlet valve cannot feed water into the boiler through the float chamber (if one is used). It must be so located as to automatically cut off the fuel supply or supply requisite feedwater when the surface of the water falls below the lowest safe water line. This lowest safe water line should not be lower than the bottom of the water glass.

b. The fuel- or feedwater-control device may be attached directly to the boiler shell or to the tapped openings provided for attaching a water glass directly to a boiler. If the connections from the boiler utilize piping, nonferrous crosses should be used at all right angles to facilitate cleaning and inspection of the pipes.

c. Designs with a float and float bowl must have a vertical straightway-valve drainpipe. The drainpipe is located at the lowest point in the water-equalizing pipe connections through which the bowl and the equalizing pipe can be flushed and the device tested.

.37 **Safety Valves.** Since the safety valve is the most important safety device on the boiler, it must be inspected with utmost care. There should be no rust, scale, or other foreign substances in the body of the valve which would interfere with its free operation. The valve must not leak under operating conditions. The opening pressure and freedom of operation of the valve should be tested, preferably by raising the steam pressure to the point of opening. If this cannot be done, the valve should be tested by opening with the try lever in accordance with the procedure in Section 595.2. If the valve has a discharge pipe, determine at the time the valve is operating whether or not the drain opening in the discharge pipe is free and in accordance with all required codes. If necessary, in order to determine the freedom of discharge from a safety valve, the discharge connection may be removed.

NOTE

A stop valve must not be placed between a steam boiler and its safety valve.

.38 **Steam Gauges.** A test gauge connection should be provided on the boiler so that the steam gauge on the boiler can be tested under operating pressure. The steam gauge should not be exposed to excessively high ambient temperatures and should be mounted with a siphon or trap between it and the boiler. Provisions should be made for blowing out the piping leading to the steam gauge.

.39 **Other Inspection Factors.** Other inspection factors include:

a. In water-tube boilers, it should be determined whether or not the proper baffling is in place. The absence of baffling often causes high temperatures on portions of the boiler structure not intended for such temperatures and, from this, a danger may arise. The location of combustion arches with respect to tube surfaces should be noted to make sure they do not cause the flame to impinge on a particular part of the boiler and produce overheating and consequent rupture of the material of the particular part.

b. Localization of heat brought about by improper or defective burner or stoker installation or operation creates a blowpipe effect upon the boiler and is cause for shutdown of the boiler until the condition is corrected.

c. If boilers are suspended, the supports and setting should be examined carefully, especially at points where the boiler structure comes near the setting walls or floor. At such points make sure that ash and soot will not bind the boiler structure and produce excessive strain on the structure due to expansion of the parts under operating conditions.

578.4 Inspecting Repairs

When repairs have been made, especially tube replacements, determine if the work has been done safely and properly. Pay special attention to excessive rolling in accessible tubes and, in difficult-to-reach tubes, underrolling. These always cause separation of the parts.

578.5 Hydrostatic Tests

If there is any doubt about the extent of a defect found in a boiler, a hydrostatic test should be performed. A hydrostatic pressure test must not exceed 1-1/2 times the maximum allowable working pressure. During the test, the safety valve must be removed from the boiler. It is suggested that the minimum temperature of the water be 70 °F and the maximum 160 °F. All controls and appurtenances unable to withstand the test pressure without damage must be removed during the test.

580 OPERATION, MAINTENANCE, AND REPAIR OF HOT-WATER BOILERS

581 STARTING A NEW BOILER

581.1 Cleaning and Filling

.11 Inspection for Foreign Objects. Prior to starting a new boiler, an inspection must be made to ensure that no foreign objects such as tools, equipment, rags, etc., are in the boiler.

.12 Check before Filling. Before putting water into a new boiler, make certain to the extent possible without actually lighting a fire in the empty boiler, that the firing equipment is in operating condition. This is necessary because raw water must be boiled (or heated to at least 180 °F) promptly after it is introduced into the boiler in order to drive off the dissolved gases that might otherwise corrode the boiler. In a hot-water heating system, the boiler and entire system (other than the expansion tank) must be full of water for satisfactory operation. The red, or fixed, hand on the combination altitude gauge and thermometer is normally set to indicate the amount of pressure required to fill the system with cold water. Water should be added to the system until the black hand registers the same as or more than the red hand. To ensure that the system is full, water should come out of all air vents when the vents are opened.

.13 Boiling-Out. The oil and grease which accumulate in a new hot-water boiler can be washed out in the following manner:

a. Add caustic soda or trisodium phosphate to the boiler water at the rate of 1 pound of chemical per 50 gallons of total water in the system.

WARNING

> Use care in handling these chemicals. Caustic soda is harmful to skin, clothing, and eyes. Do not permit either the dry material or the concentrated solution to come into contact with skin or clothing.

b. Fill the entire system with water.

c. Start the firing equipment.

d. Circulate the water through the entire system.

e. Vent the system, including the radiation.

f. Allow boiler water to reach operating temperature, if possible.

g. Circulate the water for a few hours.

h. Stop the firing equipment.

i. Carefully drain the system to a location where hot water can be safely discharged.

j. Thoroughly wash the boiler waterside using a high-pressure water stream.

k. Refill the system with fresh water.

l. Promptly bring water temperature to at least 180 °F and vent the system at the highest point.

m. Tighten handhole covers, manhole covers, and plugs while boiler is hot.

n. Put the boiler into service or on standby.

581.2 Starting a Hot-Water Boiler After Layup (Single Boiler Installation)

When starting a boiler after layup, proceed as follows:

a. Review the manufacturer's recommendations for startup.

b. Fill the boiler and system; vent air at the highest point in system.

c. Check the altitude gauge and expansion tank to ensure that the system is properly filled.

d. Set the control switch in OFF position.

e. Make sure fresh air to the boiler room is unobstructed and manual dampers are open.

f. Check the availability of fuel.

g. Vent the combustion chamber to remove unburned gases.

h. Clean the fire-scanner glass, if provided.

i. Determine the proper functioning of water-pressure regulator and electrically turn on the circulator pumps.

j. Check the temperature control(s) for proper setting.

k. Check the manual reset button on the low-water fuel cutoff and the high-limit temperature control.

l. Set the manual fuel-oil supply or manual gas valve in OPEN position.

m. Place the circuit breaker or fuse disconnect in ON position.

n. Place all boiler emergency switches in ON position.

o. Place the boiler control starting switch in ON or START position. (Do not stand in front of boiler doors or breeching.)

p. To make sure the controls shut off the burner, do not leave the boiler until it reaches the established cutout point.

q. During the temperature and pressure buildup period, periodically walk around the boiler to determine that all associated equipment and piping is functioning properly. Visually check the burner for proper combustion.

r. Immediately after the burner shuts off, inspect the water pressure and open the highest vent to determine if the system is completely full of water.

s. In the log book, enter the following:

(1) Date and time of the startup

(2) Any irregularities observed and any corrective action taken

(3) The time when the controls shut off the burner at established temperature, any tests performed, etc.

(4) Signature of operator

t. Check the safety-relief valve for leaking. Perform try lever test (see Section 567.21).

581.3 Abnormal Conditions

If any abnormal conditions occur during lighting off or temperature buildup, immediately open the emergency switch.

CAUTION

Do not attempt to restart unit until difficulties have been identified and corrected.

581.4 Condensation

Following a cold start, enough condensation may occur in a gas-fired boiler that it will appear the boiler is leaking. This condensation should stop after the boiler is hot.

581.5 Cutting In An Additional Boiler

When placing a boiler on the line with other boilers already in service, start the boiler using the above procedures, but close the supply-stop valve and the return-stop valve. Bring the boiler to the same temperature as the operating boiler and partially open the supply valve(s). If there is no unusual disturbance, such as noise, vibration, etc., slowly open the valve until it is fully open. Open the valve in the return line.

NOTE

When the stop valve at the boiler outlet is closed, the stop valve in the return line of that boiler must also be closed.

582 OPERATION

582.1 Preliminary Checks

The first things checked when going on duty are the pressure and temperature in all operating boilers.

582.2 Combination Gauge

When the boiler is cold, the stationary and moveable hands of the combination altitude/pressure gauge should be together; when the boiler is hot, the moveable hand should be above the stationary hand. The stationary hand should be aligned with the moveable hand at the time the system is initially filled, or it may be set to indicate the minimum pressure under which the system can operate and still maintain a positive pressure at the highest point in the system.

582.3 Operating Temperature and Pressure

.31 Operating Temperature. The maximum operating temperature of the boiler water should never exceed 250 °F and should be as low as possible to heat the space adequately under design conditions. Higher temperatures will accelerate any corrosion process.

.32 Operating Pressure. The failure of the safety-relief valve(s) to open at the set pressure frequently causes dangerous conditions in hot-water boilers. This failure is usually due to buildup of corrosive deposits between the disk and seat of the valve which are caused by a slight leakage or weeping of the valve. The safety-relief valve opens when the boilerwater pressure on the underside of the valve disk overcomes the closing force of the valve spring. As the force of the water pressure approaches the counteracting force of the spring, the valve tends to leak slightly and, if this continues, the safety-relief valve can stick or freeze. For this reason, the pressure between the safety-relief valve set pressure and the boiler operating pressure should be at least 10 psi or 25 percent of the boiler operating pressure, whichever is greater. The following are examples that show how to determine pressure differentials:

a. The operating pressure of a hot-water heating boiler, where the safety-relief valve is set to open at 30 psig, should not exceed 20 psig.

b. If the safety-relief valve on a hot-water heating boiler is set to open at 100 psig, the boiler operating pressure should not exceed 75 psig.

.33 Differential Limits. To ensure that the safety-relief valve closes tightly after popping and the boiler pressure is reduced to the normal operating pressure, these pressure differentials between the valve-set pressures and operating pressures must not be exceeded.

.34 Testing. Periodic testing of safety-relief valves must be carried out in accordance with Part 595 and Part 596.

583 REMOVAL FROM SERVICE

583.1 Procedures

Annually drain water from the bottom of the boiler while it is still hot (180 to 200 °F until the water runs clean, then refill the boiler to the normal water-fill pressure. If water treatment is used in the system, sufficient treatment compound should be added to condition the additional water.

583.2 Cleaning

When the hot-water boiler (any of those referred to previously) is cool, thoroughly clean the tubes and other heating surfaces and scrape the surfaces down to clean metal. Clean the smokeboxes and other areas where soot or scale may accumulate. When dry, soot is not corrosive but it can be very corrosive when it is damp. All soot must be removed from a boiler at the beginning of the nonoperating season or any extended nonfiring period.

583.3 Protection Against Corrosion

Swab the fireside heating surfaces with neutral mineral oil to protect against corrosion. If the boiler room is damp, place a tray of calcium chloride or unslaked lime in the combustion chamber and replace the chemical when it becomes mushy.

583.4 Periodic Checks

During the idle period, check the boiler occasionally and ensure it is not corroded. This is also an opportune time to repaint the exposed metal parts of the boiler and inspect and service the firing equipment and combustion chamber.

584 MAINTENANCE

584.1 Cleaning

.11 General. Clean the boiler tubes and other heating surfaces as required.

A general prediction applicable to all boilers cannot be made, so the frequency of the cleaning is best determined by trial. Clean the smokeboxes as required.

.12 **Backwashing of Water Heater.** Any water heater installed in or connected to a boiler should be backwashed periodically, using valves to reverse the direction of flow through the heater. This backwashing reduces the amount of scale accumulated at the outlet side of the heater. Continue the backwashing until the water runs clear. The backwashing may be done frequently, and the maximum interval should be determined by trial.

584.2 Draining

A clean, properly maintained heating boiler should not be drained unless there is a possibility of freezing, the boiler has accumulated a considerable amount of sludge or dirt on the waterside, or draining is necessary to make repairs. Very little sludge should accumulate in a boiler where little makeup water is added and where an appropriate water treatment is maintained at the proper strength. If it is necessary to drain the boiler and heating piping to do repair work and the various parts of the system cannot be isolated to avoid such draining, consider the installation of valves and drains at that time to prevent having to drain again. Considerable time and expense can be saved the next time repairs are necessary, and the amount of raw water required is also reduced.

584.3 Antifreeze

.31 **Type.** Antifreeze solutions used in heating systems must have an ethylene-glycol base and an added inhibitor.

.32 **Concentration.** Antifreeze concentrations must not be less than 33 percent or greater than 66 percent. (100 percent antifreeze has a freezing point of about -6 °F, while a concentration of 68 percent has a freezing point of about -92 °F, and a 50 percent solution has a freezing point of about -34 °F.)

.33 **Service Life.** The service life of an antifreeze solution depends on such factors as heating system design and condition, hours of operation, solution and metal temperatures, aeration, and the rate of contamination. Therefore, the antifreeze solution should be tested at least annually and as recommended by the antifreeze manufacturer. High metal temperatures accelerate depletion of the antifreeze inhibitors. For maximum service life, the metal temperature in contact with the solution should be kept under 350 °F. The fluid temperature should not exceed 250 °F.

.34 **Use.** Antifreeze solution is harmful or fatal if swallowed. Therefore, antifreeze solutions may be used only in closed circulating systems entirely separated from potable-water supply systems.

.35 **Expansion.** Antifreeze solutions expand more than water per given rise in temperature (i.e., a 50 percent by volume solution expands 4.8 percent by volume with a temperature increase from 32 to 180 °F, while water expands 3 percent with this same rise in temperature). Allowance must be made for this expansion when an antifreeze solution is used in a heating system.

584.4 Fireside Corrosion

.41 **General.** In Chapter 4, some of the causes of waterside corrosion have been stated and procedures recommended to minimize trouble from these sources. Boilers can also corrode on the fireside. Some fuels contain substances that cause fireside corrosion. Sulphur, vanadium, and sodium are among the materials that may contribute to this problem.

.42 Sulphur. Deposits of sulphur compounds cause fireside corrosion. The amount of sulphur in the fuel and the care used in cleaning the fireside heating surfaces determines the probability of corrosion. Particular care must be taken when preparing a boiler for a period of idleness. In an idle boiler, keeping the boiler heating surfaces dry will also prevent this problem.

.43 Vanadium and Sodium. Deposits of vanadium, or vanadium and sodium compound, also cause fireside corrosion. These compounds may be corrosive during the season that boilers are in service.

.44 Cleaning. The person responsible for boiler maintenance must be certain that the fireside surfaces of thboilers are thoroughly cleaned at the end of the firing season. Also, the maintenance person should observe the fireside surfaces and, if signs of abnormal corrosion are discovered, a reputable consultant should be engaged.

584.5 Safety-Relief Valves

Safety-relief valves on hot-water heating and hot-water supply boilers should be tested for proper operation in accordance with Part 595. ASME-rated valves must be installed on the boiler. When replacement is necessary, use only ASME-rated valves of the required capacity.

584.6 Burner Maintenance

.61 Oil Burners. Oil burners require periodic maintenance to keep the nozzle and other parts clean. This periodic maintenance consists of the following:

a. Check and clean the oil-line strainers.

b. Inspect the nozzle and the oil level in the gear cases.

c. Check and clean all filters, air-intake screens, blowers, and air passages.

d. Check all linkages and belts and adjust as required.

e. Lubricate all parts in accordance with the manufacturer's recommendations.

f. Check the pilot burners and ignition equipment for proper flame adjustment and performance.

.62 Gas Burners. Maintenance on gas burners is performed as follows:

a. Check the gas burners for dirt, lint, or foreign matter. Ensure all ports, gas passages, and air passages are free of obstructions.

b. Linkages, belts, and moving parts on power burners must be checked for proper adjustment.

c. On combination oil and gas burners, after prolonged periods of oil firing the gas outlets may become caked with carbon residue from unburned fuel oil. Check for carbon residue and clean if necessary.

d. Lubricate all parts in accordance with the manufacturer's recommendations.

e. Check to determine if the pilot is clean and properly located to permit ready observation.

f. Check the burners and ignition equipment for proper flame adjustment and performance.

584.7 Low-Water Fuel Cutoff and Water Feeders

Maintenance procedures for low-water fuel cutoffs and water feeders are as follows:

a. Low-water fuel cutoffs and water feeders must be dismantled annually by qualified personnel to the extent necessary to ensure freedom from obstructions and the proper functioning of all working parts.

b. Inspect the connecting lines to the boiler for mud, scale, etc., and clean as required.

c. Examine all visible wiring for brittle or worn insulation and ensure the electrical contacts are clean and functioning properly.

d. Give special attention to solder joints on the bellows and float (when this type of control is used).

e. Check the float for evidence of collapse and the mercury bulb (where applicable) for mercury separation or discoloration.

NOTE

Do not attempt to repair mechanisms in the field.

Complete replacement mechanisms, including necessary gaskets and installation instructions, are available from the manufacturer.

f. Reassemble and test, if installation permits, without draining water from the boiler.

584.8 Flame Safeguard Maintenance

.81 Thermal-Type Detection Device. Check the device for electrical continuity and satisfactory current generation in accordance with the manufacturer's instructions. After completing maintenance, test as per Part 592.

.82 Electronic-Type Detection Device. Annually, replace the vacuum tubes or transistors with the type recommended by manufacturer. Check operation of the unit in accordance with the manufacturer's instructions and examine the device for damaged or worn parts.

NOTE

Do not attempt to repair these units in the field.

Replacement assemblies are available from the manufacturer on an exchange basis.

584.9 Limit-Control Maintenance

Maintenance on the temperature-limiting control is generally confined to a visual inspection of the device for evidence of wear, corrosion, etc.. If the control is a mercury-bulb-type, check for mercury separation and discoloration of bulb.

NOTE

If the control is defective, replace it. Do not attempt to make field repairs.

585 CAST-IRON BOILER MAINTENANCE

585.1 Heating Surfaces

Check the firebox gas passages and breeching for soot accumulation. Use a wire brush and vacuum cleaner, if required, to remove the soot or other dirt.

585.2 Internal Surfaces

.21 **Cleaning.** If there is considerable foreign matter in the boiler water, the boiler must be allowed to cool, then must be drained and thoroughly flushed out. Remove the washout plugs and wash through the openings with a high-pressure water stream. This will normally remove any sludge or loose scale. If there is evidence that hard scale has formed on the internal surfaces, the boiler must be cleaned by chemical means, as prescribed by a qualified water-treatment specialist.

.22 **Inspection.** When practical, use a flashlight in preference to an extension light for internal inspection purposes. If an extension light is taken into a boiler, ensure the cord is rugged, in good condition, and properly grounded, and is equipped with a vapor-tight globe, substantial guard, and nonconducting holder and handle.

585.3 Leaking Tubes

If one tube in a boiler develops a leak due to corrosion, it is likely that other tubes are corroded also. Have the boiler examined by a capable and experienced inspector before ordering the replacement of any tubes. If all the tubes will need replacement soon, it is preferable and less expensive to have all the work done at one time.

585.4 Use of Sealants

Sealants have a detrimental effect on boilers, pumps, safety-relief valves, etc. Their use is prohibited in hot-water heating or hot-water supply boilers.

585.5 Circulating Pumps and Expansion Tanks

Inspect and lubricate the circulating pump(s) in accordance with the manufacturer's instructions, and check the operation of all associated controls, switches, etc. Examine expansion tank for dirt, leaks, and corrosion. Clean and repair as required. For detailed instructions, refer to the manufacturer's literature, instructions, and data.

585.6 Maintenance Schedule of Boilers in Service

.61 **General.** Listed below are suggested frequencies for the various routines and tests to be performed in connection with boiler inspection and maintenance. An example of this schedule in checklist form is shown in Appendix C, Exhibit 5-4.

.62 **Daily Procedures.** Follow these procedures:

a. Observe operating pressures and temperature and general conditions.

b. Determine the cause of any unusual noises or conditions and make necessary corrections.

.63 **Weekly Maintenance.** Follow these procedures:

a. Observe condition of flame. If flame is smoky or if burner starts with a puff, repair (for oil burners, observe daily).

b. Check the fuel supply (oil burners only).

c. Observe the operation of circulating pump(s).

.64 **Monthly Maintenance.** Follow these procedures:

a. Perform a try-lever test on the safety-relief valve.

b. Test the flame detection devices.

c. Test the limit controls.

d. Test the operating controls.

e. Check the boiler room floor drains for proper functioning.

f. Inspect the fuel-supply systems in the boiler room area.

g. Check the condition of the heating surfaces (for preheated oil installation, inspect twice a month).

h. Perform the combustion and draft tests (preheated oil only).

i. If piping arrangement permits (without draining considerable water from the boiler) test low-water fuel cutoff and/or water feeder.

.65 **Annual Maintenance.** Annually perform the following:

a. An internal and external inspection after thorough cleaning

b. Routine burner maintenance

c. Routine maintenance of circulating pump and expansion tank equipment

d. Routine maintenance of entire combustion-control equipment

e. Combustion and draft tests

f. A safety-relief valve--pop test

g. A slow-drain test of low-water cutoff

h. An inspection of the gas piping for proper support and tightness

i. An inspection of the boiler room ventilation louvers and intake

586 BOILER REPAIRS

586.1 Safety

Do not permit repairs to a boiler while it is in service or under pressure, except with the approval and under the supervision of an authorized boiler inspector or responsible engineer. Take every precaution necessary to protect anyone working in the boiler room, particularly anyone working inside the boiler or in the combustion chamber of the boiler. Pull the main burner switch, lock it out, and tag it with Form 4707, Out of Order. Swing the burner out of place, if possible, and close and lock valves, etc. Always have one person standing by outside when someone is working inside a boiler.

586.2 Notification

When repair work is required, notify the authorized boiler and pressure vessel inspector and follow that inspector's recommendations.

586.3 Welding

All repair work should be done by experienced boiler mechanics. All welding must be done by qualified welders, using proper procedures.

587 TESTS AND INSPECTIONS

587.1 Purpopse

.11 **Installation Inspection.** This inspection differs from the inspection during manufacture, which pertains primarily to conforming to code construction requirements. This inspection determines if boiler supports, piping arrangements, safety-relief valves, other valves, water columns, gauge cocks, altitude gauges, thermometers, controls, and other apparatus on the boiler meet code and/or other jurisdictional requirements.

.12 **Periodic Reinspections.** The main purposes of reinspection include protection against loss of or damage to the pressure vessel because of corrosion, pitting, unsafe operating conditions possibly caused by changes in piping or controls, or lack of testing of safety devices. It is important that inspections be thorough and complete. To ensure that all important elements are checked, the following recommended directions and instructions for such inspections are given. The tests recommended for burner efficiency, combustion safeguards, safety controls, operating controls, limit controls, safety valves, and safety-relief valves are included in Part 590.

587.2 Preparing Boilers for Inspection

Whenever an inspection is scheduled, all hot-water heating and supply boilers should be prepared for inspection by the owner or user.

Before inspection, every accessible part of a boiler must be open and properly prepared for examination, both internally and externally. In cooling down a boiler for inspection or repairs, the water must not be withdrawn until the setting is sufficiently cooled to avoid damage to the boile. When possible, the boiler should be allowed to cool down naturally.

The boiler should be prepared for internal inspection in the following manner:

a. Water should be drained and the boiler washed thoroughly.

b. All manhole and handhole plates, washout plugs, and water-column connections should be removed and the furnace and combustion chambers thoroughly cooled and cleaned.

c. All grates in internally fired boilers should be removed.

d. Brickwork should be removed as required by the inspector in order to determine the condition of the furnace, supports, or other parts.

e. Any leakage of hot water into the boiler should be cut off by disconnecting the pipe or valve at the most convenient point.

It is not necessary to remove insulation material, masonry, or fixed boiler parts unless defects or deterioration are suspected. Where there is moisture or vapor showing through the covering, the covering must be removed at once and a complete investigation made to determine the cause. Some coverings contain asbestos and require special handling. Every effort must be made to discover the true condition, even if it means drilling holes or cutting away parts.

587.3 Inspection

.31 Procedure. The inspector should get as close as possible to boiler parts in order to obtain the best possible vision of the surface. The inspector should use a good artificial light if natural light is inadequate. Whenever the inspector deems it necessary to test boiler apparatus, controls, etc., these tests should be made by a plant operator in the presence of the inspector unless otherwise ordered.

.32 Corrosion. Corrosive materials are as follows:

a. Surfaces. The inspector should examine all surfaces of the exposed metal inside the boiler to detect any corrosion caused by treatment, scale solvents, oil, or other substances which may have entered the boiler. Any evidence of oil should be noted carefully, since even a small amount is dangerous. Immediate steps must be taken to prevent the entrance of any more oil into the boiler. Oil or scale on plates above the boiler fire is particularly dangerous, often causing sufficient weakening to bag or rupture the plates.

b. Seams and Joints. Corrosion along or immediately adjacent to a seam is more serious than a similar amount of corrosion in the solid plate away from the seams. Grooving and cracks along longitudinal seams are especially significant, since they are likely to occur when the material is highly stressed. Severe corrosion is likely to occur at points where the circulation of water is poor; such places should be examined very carefully. For the purpose of estimating the effect of corrosion or other defects upon the strength of a shell, a comparison must be made with the efficiency of the longitudinal joint of the same boiler, the strength of which is usually less than that of the solid sheet.

.33 Stays, Manholes, and Openings. Inspection of stays, manholes, and openings should be as follows:

a. Stays. All stays, diagonal or through, should be examined to see if they are in even tension. All fastened ends should be examined to note if cracks exist where the plate is punched or drilled. If stays are not found in proper tension, then proper adjustment must be made.

b. Manholes and Openings. The manhole(s) and other reinforcing plates, as well as nozzles and other connections flanged or screwed into the boiler, must be examined both internally and externally to determine if they are cracked or deformed. Whenever possible, observation should be made from the inside of the boiler to check the thoroughness with which the pipe connections are made to the boiler. All openings to external attachments, such as connections to a low-water cutoff and openings to safety-relief valves, should be examined to ensure their freedom from obstruction.

.34 Fire Surfaces, Lap Joints, and Tubes. Inspection of fire surfaces, lap joints, and tubes should be as follows:

a. Fire Surfaces. Particular attention should be given to any plate or tube surface exposed to fire. The inspector should observe whether or not any part of the boiler has become deformed (bulging or blistering) during operation. If bulges or blisters are large enough to seriously weaken the plate or tube, especially if water is leaking from such a defect, the boiler must be removed from service until the defective part or parts have received proper repairs. Carefully watch for leaking from any part of the boiler structure, particularly in the vicinity of seams and tube ends. Firetubes sometimes blister but rarely collapse. The inspector should examine the tubes for blistering and, if necessary, have them replaced.

b. Lap Joints. Lap-joint boilers are apt to crack where the plates lap in the longitudinal or straight seam. If there is any sign of leakage or other distress at this joint, it should be investigated thoroughly to determine if cracks exist in the seam. Any cracks noted in shell plates are usually dangerous.

NOTE

> Staybolts should be tested by tapping one end of each bolt with a hammer. When possible, holding a hammer or other heavy tool at the opposite end makes the test more effective. A dull sound may indicate deterioration of the

c. Tubes. Tubes in horizontal firetube boilers deteriorate more rapidly at the ends near the fire. These ends should be carefully tapped on their outer surface with a light hammer to determine if there has been a serious reduction in thickness. Without water cooling, the tubes of vertical tubular boilers are more susceptible to deterioration at the upper ends when exposed to fire or heat. They should be inspected by reaching as far as possible through the handholes (if any), as well as inspected at the ends. The tube surfaces must be carefully examined to detect bulges, cracks, or any evidence of defective welds. If exposed to a strong draft, tubes may become thinned by the erosion produced by the impingement of particles of fuel and ash. A leak from any tube frequently causes serious corrosion on a number of neighboring tubes. The ligaments between tube holes in the heads of all fire-tube boilers and in shells of water-tube boilers must be examined. If any leakage is noted, broken ligaments are probably the reason.

.35 **Pipes.** Inspection of pipes should be as follows:

a. All piping should be examined for leaks; if any are found, it must be determined whether they are the result of excess strain due to expansion, contraction, or some other cause. The general arrangement of the piping in regard to the provisions for expansion and drainage, as well as adequate support at the proper points, should be carefully noted.

b. The arrangement of connections between individual boilers and the supply and return headers should be especially noted to ensure that any change in position of the boiler (due to settling or other causes) has not placed an undue strain on the piping.

c. Determine whether all pipe connections to the boiler have the proper strength in their fastenings, whether tapped into or welded to the boiler shell. The inspector should ensure that there is proper provision for the expansion and contraction of piping and that no undue vibration could damage parts. This includes all water pipes. Special attention should be given to the blowoff pipes and their connections and fittings, because the expansion and contraction due to rapid changes in temperature and water-hammer action cause a great strain upon the entire blowoff system. The freedom of the blowoff and drain connection on each boiler should be tested, whenever possible, by opening the valve for a few seconds, at which time it can be determined whether or not there is excessive vibration.

.36 **Low-Water Cutoff.** All automatically fired hot-water heating or supply boilers must be equipped with an automatic low-water fuel cutoff that is located where it can automatically cut off the fuel supply when the surface of the water falls below the lowest safe water line. Such a fuel-control device may be attached directly to the boiler shell or to the tapped openings provided for attaching a water glass directly to a boiler. Designs having a float and float bowl must have a vertical straightway-valve drainpipe through which the bowl and the equalizing pipe can be flushed and the device tested. The drainpipe is located at the lowest point in the water-equalizing pipe connections.

.37 **Safety-Relief Valves.** Since the safety-relief valve is the most important safety device on the boiler, it must be inspected with the utmost care. There should be no rust, scale, or other foreign substances in the body of the valve that could interfere with its free operation. The valve must not leak under operating conditions. The opening pressure and freedom of operation of the valve should be tested, preferably by raising the water pressure to the point of opening (see Part 590). If the valve has a discharge pipe, determine at the time the valve is operating whether or not the drain opening in the discharge pipe is free and in accordance with all required codes necessary. In order to determine the freedom of discharge from a safety-relief valve, the discharge connection may be removed.

NOTE

A stop valve must not be placed between a boiler and its safety-relief valve.

.38 **Combination Temperature and Pressure Gauges.** A test-gauge connection should be provided on the boiler so that the gauge on the boiler can be tested under operating conditions. The gauge must not be exposed to excessively high ambient temperatures.

.39 **Other Inspection Factors.** Other inspection factors are:

a. In water-tube boilers, it should be noted whether or not the proper baffling is in place. The absence of baffling often causes high temperatures on portions of the boiler structure that are not intended for such temperatures and, from this, a dangerous condition may result. The location of combustion arches with respect to tube surfaces must be noted to make sure they do not cause the flame to impinge on a particular part of the boiler and produce overheating and consequent rupture of the material of the part.

b. Localization of heat brought about by improper or defective burner or stoker installation or operation creates a blowpipe effect upon the boiler and is cause for shutdown of the boiler until the condition is repaired.

c. Where boilers are suspended, the supports and setting must be examined carefully, especially at points where the boiler structure comes near the setting walls or floor. At such points make sure that ash and soot will not bind the boiler structure and produce excessive strains on the structure due to the expansion of the parts under operating conditions.

587.4 Inspecting Repairs

When repairs have been made, especially tube replacements, determine if the work has been done safely and properly. Pay special attention to excessive rolling in accessible tubes and, in difficult-to-reach tubes, underrolling. These always cause separation of the parts.

587.5 Hydrostatic Tests

If there is any doubt about the extent of a defect found in a boiler, a hydrostatic pressure test should be performed. A hydrostatic pressure test must not exceed 1-1/2 times the maximum allowable working pressure. During the test, the safety-relief valve must be removed from the boiler, as well as all controls and appurtenances unable to withstand the test pressure without damage. It is suggested that the minimum temperature of the water be 70 °F and the maximum 160 °F.

590 BOILER TESTING

591 GENERAL

Periodic testing of all important components is required to maintain good working conditions and ensure safety. Adequate precautions must be taken while tests are being performed to protect personnel conducting the tests, building occupants, and equipment. In addition to the usual mechanic tools, one or more test leads, a test pressure gauge, a test thermometer, and volt-ohm-meter be required in connection with certain tests. The test leads should consist of approximately 3 feet of insulated No. 14 gauge stranded wire equipped with properly insulated alligator clips. The test gauge should be a good quality inspector's gauge, graduated in increments of not more than 1 pound each. These gauges require periodic calibration. This can be done only in a properly equipped laboratory.

The thermometer should read at least as high as 400 ^{o}F, with no more than 2 degrees per graduation.

592 FLAME-SAFEGUARD DEVICE TESTING

592.1 Gas--Thermal-Type

Follow these procedures:

a. While the burner is in operation, shut off the manual gas valve.

b. Turn off the pilot gas cock and time the interval for the automatic gas valve to close. This time must not exceed that recommended by the manufacturer.

c. If the test in Section 592.1b is okay, relight the pilot, turn on the main gas valve, and allow the burner to fire.

d. Check the burner for proper operation.

592.2 Oil--Thermal-Type, Stack Switch

Follow these procedures:

a. Shut off the manual valve in the oil-supply line and time the interval required for the oil solenoid valve to close. Check this time against that recommended by the manufacturer.

b. If the test in Section 592.2a is okay, refire the burner and observe its operation.

c. The manual shutoff must be a gate valve installed just ahead of the oil solenoid valve.

592.3 Gas--Electronic Flame Rod With Standing Pilot

Follow these procedures:

a. With the burner firing normally, turn off the main gas cock.

b. Turn off the pilot gas cock and time the interval required for the safety shutoff gas valve to close (should be 4 seconds or less); check with the manufacturer's data.

c. If the test in Section 592.3b is okay, relight the pilot, reset the controls, and fire the boiler. Observe the boiler operation.

592.4 Gas--Electronic Flame Rod With Interrupted Ignition (And Gas Electronic Flame Scanner)

Follow these procedures:

a. With the burner firing normally, turn off the main gas cock and time the interval for the shutoff gas valve to close (should be 4 seconds or less); check with the manufacturer's data.

b. If the test in Section 592.4a is okay, open the main gas cock, reset the controls, and fire the burner. Observe the boiler operation.

592.5 Oil or Gas--Electronic Flame-Scanner

Follow these procedures:

a. With the burner firing normally, shut off the manual valve in the oil- or gas-supply line and time the interval for the solenoid valve to close (should be 4 seconds or less); check with the manufacturer's data.

b. If the test in Section 592.5a is okay, open the manual valve, reset the controls, and refire the burner. Observe the boiler operation.

592.6 Oil or Gas--Electronic-Type with Proven Pilot-Flame Detection

Follow these procedures:

a. With the burner in OFF cycle, manually shut off the fuel to the main burner and the pilot burner.

b. Operate the necessary control to start the main burner.

c. After the prepurge period, the pilot assembly will be energized but, because no flame is detected, the automatic pilot valve will shut off in about 10 seconds, and the main automatic fuel valve will not be energized.

d. If the test in Section 592.6c is okay, open the manual valve to PILOT and reset the controls. Test the main burner for flame detection.

e. Test gas as per Section 592.4.

f. Test oil as per Section 592.5.

592.7 Pilot Turndown Test

Following is information for the pilot turndown test:

a. This test is required to prove that the main automatic fuel valve cannot be energized when the pilot flame is in a condition that prevents the main burner from igniting safely.

b. If the above condition exists, the flame-detection device must be adjusted to function properly.

c. Since each device may require different procedures, consult the manufacturer's instructions for making this test.

593 COMBUSTION-EFFICIENCY TESTS

593.1 General

A combustion-efficiency test must be made on each fuel-burning unit at least once each year; on gas-fired units with nonadjustable secondary air, only the draft and stack temperature need be checked. More frequent tests should be made on large units and on boilers burning preheated oil. If burners have variable firing rates, their efficiency must be checked at the different rates.

593.2 Oil Burners

.21 Over-the-Fire Draft. Measure the over-the-fire draft and compare it to that recommended by the burner manufacturer. Adjust the secondary air as required. This reading should range from 0.02 to 0.05 inches of water negative pressure for natural or induced-draft installations up to 5 gallons/hour. Readings for forced-draft installations will be somewhat higher and will be positive pressure readings. If necessary, a small hole may be drilled in the firebox door to accommodate the draft gauge. On forced-draft units, the hole must be plugged when not in use.

.22 Smoke Readings. Following manufacturer's instructions, use a smoke-measuring instrument to obtain a smoke reading. No unit should be allowed to operate with a smoke density in violation of local codes. Air adjustments, nozzle conditions, nozzle location, combustion chamber size, and air leakage all affect the fuel combustion.

.23 Carbon Dioxide (CO_2) Readings. Using the CO_2 analyzer, take a reading in the breeching ahead of any openings (barometric dampers, cleanouts, etc.). A small hole may be drilled for this purpose. The theoretical percent of CO_2 ranges from 15 percent for No. 1 and No. 2 oil to 16.5 percent for No. 6 oil. Actual readings should range from 9 to 12 percent for light oil and from 10 to 14 percent for heavy oil. Adjustments should be made to provide the highest CO_2 reading without smoke. Reduced secondary air resulting from a dirty fan or a change in barometric conditions may cause smoking at the higher CO_2 readings.

.24 Stack Temperature. Measure the stack temperature at the same point that the CO_2 readings were taken. Subtract the room temperature from this reading;

the result will be the net stack temperature. The net stack temperature should range from 400 to 600 °F. About 500 °F is desirable for modern units designed to burn oil. Units converted from coal will run somewhat higher. Low stack temperatures cause condensation and deterioration of the brickwork, whereas high stack temperatures indicate that the heat of combustion is not being absorbed by the heat-transfer surfaces of the boiler. Insufficient draft may cause low stack temperature and poor combustion, whereas excess draft can result in high stack temperature. The result in either case is a loss in boiler efficiency.

.25 **Adjustments.** After the tests are made in the order listed above, adjustments should be made to bring the readings within the proper range; however, do not sacrifice one measurement to improve another beyond practical limits. After correcting one reading, recheck the others to determine that they are still within the proper range. The percent CO_2 draft, smoke density, and stack temperature should be regulated to provide the best overall safe boiler efficiency.

593.3 Gas Burners

.31 **Over-the-Fire Draft.** Measure the over-the-fire draft and compare it to that recommended by the burner manufacturer. Adjust the secondary air as required. This reading should range from 0.02 to 0.05 inches water negative pressure for natural- or induced-draft installations. Readings for forced-draft installations will be somewhat higher and will be positive pressure readings. If necessary, a small hole may be drilled in the firebox door to accommodate the draft gauge. On forced-draft units, the hole must be plugged when not in use.

.32 **Carbon Dioxide (CO_2) Readings.** Using the CO_2 analyzer, take a reading in the breeching ahead of any openings (barometric dampers, cleanouts, etc.). A small hole may be drilled for this purpose. The theoretical percent of CO_2 for natural gas is approximately 12 percent. Actual readings should range from 7 to 10 percent, depending on the amount of excess combustion air. Adjustments should be made to provide the highest CO_2 reading while maintaining proper flame color and shape. This test is not required for boilers with nonadjustable secondary air inlets and draft hood.

.33 **Stack Temperature.** Measure the stack temperature at the same point that the CO_2 readings were taken. Subtract the room temperature from this reading; the result will be the net stack temperature. This should range from 400 to 600 °F, which is desirable for modern units designed to burn gas. Units converted from other fuels may run higher at a higher temperature. Low stack temperatures cause condensation and deterioration of the brickwork, whereas high stack temperatures indicate that the heat of combustion is not being absorbed by the heat-transfer surfaces of the boiler. Insufficient draft may cause low stack temperature and poor combustion, whereas excess draft can result in high stack temperature. Both cause a loss in boiler efficiency. If problems are encountered with boilers having nonadjustable secondary air inlets and draft hood, consult the manufacturer.

.34 **Adjustments.** After the tests are made in the order listed above, adjustments should be made to bring the readings within the proper range; however, do not sacrifice one measurement to improve another beyond practical limits. After correcting one reading, recheck the others to determine that they are still within the proper range. The draft, percent of CO_2, and stack temperature must be regulated to provide the best overall safe boiler efficiency.

593.4 Draft Measures at the Boiler Breeching

To check the accuracy of the draft measurement, an additional reading may be taken at the breeching on the furnace side of any draft regulators, cleanouts, etc. This reading will probably range from 0.07 to 0.10 inches of water negative pressure for natural- or induced-draft installations. For forced-draft units, the reading will be less than the over-the-fire draft, but should be a positive pressure. Both readings must be recorded when the heat-transfer surfaces are clean and the boiler properly adjusted. They can then be compared to later periodic readings. For example, if the readings at the breeching remained constant, and the over-the-fire reading changed, this would indicate a possible inaccuracy in the over-the-fire measurement. If the difference between the two readings increased, this would indicate a soot buildup or other restriction in the combustion chamber or gas passages (tubes). This is helpful in determining the need for cleaning the heat-transfer surfaces of the boiler. This measurement is primarily used to check oil-burning units and large forced-draft, gas-fired units.

594 LIMIT-CONTROL TESTS

594.1 General

All limit controls must be tested periodically. Consult the manufacturer's data for complete details. A test gauge should be used to check the operation of all pressure controls. In general, the tests are to be performed as follows.

594.2 High-Limit Steam-Pressure Control

To test the high-limit, steam-pressure control, disconnect power to the boiler controls and place a test lead across the contacts of the operating steam-pressure controller. Check the setting of the high-limit control; it should be higher than the setting of the operating control, but lower than 15 psi. Restore power to the controls and fire the boiler. Allow boiler to fire until steam pressure reaches the high-limit control setting. The control should operate at this point, and shut off the flow of fuel to the burner. If the control performs as expected, disconnect the power and remove the test lead. Reset the high-limit control and fire the boiler. Observe the boiler for proper operation.

594.3 Draft-Limit Control

This control must be tested to determine if it will shut down the burner when the over-the-fire draft falls below the minimum allowable 0.02 inches water. Using a draft gauge to measure the over-the-fire draft, restrict the flow of secondary air until the draft drops slightly below 0.02 inches water. At this point, the burner should cut off. Do not completely shut off the secondary air during this test. If the control shuts down the burner, reset the controls and refire the boiler. If the control does not shut off the burner, adjust or replace it as required. On natural- or induced-draft installations, the draft gauge will measure a negative pressure difference, the pressure over the fire being less than room pressure; whereas, for forced-draft installations, the gauge will measure a positive pressure.

594.4 Boiler Room Temperature-Limit Switch Control

Some installations have a temperature-limit switch control or other device that will shut down the burner in the event of a rise in temperature in the vicinity of the boiler. These devices protect against flashbacks, oil fires, and overheated boilers. If possible, trip the device manually while the burner is firing; the burner should shut down. If the burner does shut down, reset the device, refire the boiler, and check operation. If the device cannot be operated manually, shut down the boiler, disconnect the power, and open the control-circuit through device. Attempt to refire the boiler; it should not operate. If the boiler does not operate, reconnect circuit, fire boiler, and check operation.

594.5 Electrical-Current Limit Controls

All electrical-current limiting or overload devices, including fuses and thermal overload elements, must be inspected to determine if they are properly sized and in good condition. Switches, starters, and relays must be checked for proper operation.

594.6 Low Gas-Pressure Control

Check the manufacturer's data to determine the minimum allowable operating gas pressure to the burner. Connect a manometer to the gas manifold just ahead of the burner. With the burner firing normally, close the main gas cock gradually until the pressure drops to the minimum specified by the manufacturer. The burner should shut off. If the burner shuts off, reset the controls, refire the boiler, and check burner operation.

594.7 High Gas-Pressure Control

(For systems where high-pressure gas over 1 pound is furnished upstream of the regulator) Check the manufacturer's instructions for the maximum operating pressure of the burner. Connect a manometer to the gas manifold just downstream of the pressure regulator. With the burner shut down, adjust the pressure regulator to provide pressure slightly in excess of this maximum operating pressure. Operate the burner controller to call for heat; the burner should not start. If the burner does not start, readjust the pressure regulator to normal burner operating pressure and check burner operation.

594.8 Oil Pressure Supervisory Switch

(On installations with separate pump set) Manually turn down the burner cock until the oil pressure drops below the minimum recommended by the burner manufacturer. The burner should shut off. If the burner performs as expected, reset the burner cock, restart the burner, and check burner operation.

594.9 Air-Pressure Supervisory and Emergency Disconnect Switch

.91 **Air-Pressure Supervisory Switch.** Check the manufacturer's instructions for the minimum static pressure required. Adjust the air damper to decrease air to the burner; the burner should shut off when the pressure drops below the minimum recommended air pressure. If the burner shuts off, readjust air damper to desired air pressure and check burner operation.

.92 **Emergency Disconnect Switch.** All boilers must be equipped with an emergency disconnect switch located outside the boiler room door. To test it, throw the switch to the OFF position while the boiler is operating. This should kill all power to the controls and the boiler should shut down completely. If the boiler shuts down completely, restore the switch, refire the boiler, and observe for proper burner operation. On units equipped with program controls, the burner controls should completely recycle before refiring.

595 SAFETY VALVE TEST (STEAM BOILERS)

595.1 Safety

As a precautionary measure, all personnel concerned with conducting a pop or capacity test must be briefed on the location of all shutdown controls in the event of an emergency, and at least two people must be present during this test. Protect those present from any escaping steam.

595.2 Try-Lever Test

For every month that the boiler is in operation or after any period of inactivity, a try-lever test should be performed. With the boiler under a minimum of 5 psig pressure, lift the try lever on the safety valve to the wide-open position and allow steam to be discharged for 5 to 10 seconds. Release the try lever and allow the spring to snap the disk to the closed position. If the valve simmers, operate the try lever two or three times to allow the disk to seat properly. If the valve continues to simmer, it must be replaced, or have it repaired by an authorized representative of the manufacturer. Visually inspect the valve for evidence of scale or encrustation within. Do not disassemble the valve or attempt to adjust the spring setting. A chain attached to the try lever of the valve facilitates this test, and allows it to be conducted in a safe manner from the floor. The date of this test must be entered into the boiler log book.

595.3 Pop Test

An open pop test of a safety valve is conducted to determine if the valve will open under boiler pressure at operating temperatures within the allowable tolerances. It must be conducted annually, preferably at the beginning of the heating season if the boiler is used only for space-heating purposes. Hydrostatic testing (using water) is not to be considered as an acceptable test to check the safety valve opening pressure. A recommended procedure is as follows:

a. Establish the necessary trial conditions at the particular location. If necessary, provide adequately supported temporary piping from the valve discharge to a safe location outside the boiler room. In some installations, temporary ventilation may satisfactorily dispose of the steam vapor. Review the preparation for the test with all personnel involved. At least two people must be present at all such tests.

b. Install a temporary, calibrated test-pressure gauge to check the accuracy of the boiler gauge.

c. Isolate the boiler, if possible, by shutting the stop valves in the steam supply and condensate-return piping.

d. Temporarily place test leads across the appropriate terminals on the operating control to demonstrate the ability of the high-limit pressure control to function properly. After this has been checked, place another set of test leads across the high-limit pressure control terminals to permit continuous operation of the burner.

e. The safety valve should pop open at an acceptable pressure; i.e., 15 psig plus or minus 2 psig. A simmering action will ordinarily be noticed shortly before the valve pops to the open position.

f. If the valve does not open in the 13 to 17 psig range, it should be replaced or repaired. It is not necessarily a dangerous situation if the valve opens below 13 psig, but it could indicate a weakening of the spring, improper setting of the spring, etc. If the valve does not open at 17 psig, shut off the burner and dissipate the steam to the system by slowly opening the supply valve. When the pressure has dropped sufficiently, open the valve using the try-lever test method. If this releases the disk from the seat, continue with the pop test procedure as previously described. If the valve still does not open at or below 17 psig, it must be replaced with a new valve, returned to the manufacturer for repair, or field repaired by the manufacturer.

g. If the valve pops open at an acceptable pressure, immediately remove the test leads from the high-limit pressure control. The burner main flame should cut off as soon as the test leads are removed.

h. The safety valve will stay open until the pressure in the boiler drops sufficiently to allow the valve to close, usually 2 to 4 psig below the opening pressure. This pressure drop (blowdown) is usually indicated on the safety valve nameplate.

i. Relieve the higher pressure steam to the rest of the system by slowly opening the steam-supply valve. After the boiler and supply piping pressures have become equalized, open the return valve.

j. Remove the test leads from the operating control and check to make certain that the control functions properly. This is best done by allowing the control to cycle the burner on and off at least once.

k. Enter the necessary test data into the boiler log book.

595.4 Capacity Test

Capacity tests should be performed on safety valves on all new boiler installations and when any safety valve is repaired or replaced. The tests should also be made on existing boiler installations when any modification is made that affects the steam-generating capacity of the boiler, such as changing the size of the burner, the rate of fuel flow, or the grade or type of fuel not previously fired. Follow these procedures:

a. At least two people should be present at all such tests.

b. Establish all necessary general trial conditions at the particular location. If necessary, provide adequately supported temporary piping from the safety valve discharge to a safe location outside the boiler room. In some installations, temporary ventilation may satisfactorily dispose of the steam vapor. Review the preparation for the test with all personnel involved.

c. A calibrated test gauge must be temporarily installed to check the accuracy of the boiler pressure gauge during all phases of these tests.

d. Isolate the boiler, if possible, by shutting the stop valves in the supply and return piping of the boiler. The water feeder should be able to operate during the test,if it is necessary to do so. It may be necessary to manually feed 1 or 2 inches of water to the boiler to prevent the low-water fuel cutoff from shutting down the burner.

e. Set the burner to operate at its maximum capacity and ensure that combustion is complete with proper over-the-fire draft.

f. When the operating control has shut off the burner, place test leads across the control terminals to switch the control to the high-pressure cutout.

g. When the high-pressure cutout has demonstrated its ability to shut off the burner, place another set of test leads across its terminals, reset it if it has this feature, and allow the burner to continue running without control.

h. The safety valve should pop open at the set pressure (15 psig, plus or minus 2 psig) or within the range of 13 to 17 psig. If it opens below 13 psig or does not open at 17 psig, it should be replaced or repaired by the authorized representative of the safety valve manufacturer.

i. If the safety valve opens within this range, continue running the burner. If the pressure continues to rise, allow it to reach a maximum and hold it for a minimum of 30 seconds. The maximum reached must not exceed 20 psig.

j. If the pressure continues to rise above 20 psig, the burner should be stopped by removing the test leads from the high-pressure cutout. If the boiler room is filled with steam, the disconnect switch at the door may be used. The safety valve must be replaced by one that demonstrates its ability to maintain a pressure of not more than 20 psig in the boiler.

k. If the safety valve does maintain a maximum pressure of 20 psig or below, the burner should be stopped by removing the test leads from the high-pressure cutout. Observe the pressure at which the safety valve closes.

l. Remove the test leads from the operating control and let the burner cycle once to determine whether or not it is functioning properly.

m. Enter all pertinent data in the boiler room log--date, time, personnel present, opening pressure, maximum pressure, closing pressure, and any other pertinent information.

596 SAFETY-RELIEF VALVE TESTS (WATER BOILERS)

596.1 Try-Lever Test

Every month that the boiler is in operation or after any prolonged period of inactivity, a try-lever test must be performed as follows:

a. Lift the try lever to the open position and hold it open for at least 5 seconds or until the water discharged runs clear.

b. Release the lever and allow the spring to snap the disk to the closed position. If the valve leaks, operate the try lever two or three times to clear the seat of any object which is preventing proper seating. As safety-relief valves are normally piped to the floor or near a floor drain, it may take some time to determine if the valve has shut completely.

c. If the safety-relief valve continues to leak, it must be replaced with a new valve, returned to the manufacturer for repair, or field repaired by the manufacturer.

596.2 Pop (Pressure Relief) Test

A pop (pressure-relief) test must be performed annually, preferably at the beginning of the heating season if the boiler is shut off during the summer months. Follow these procedures:

a. Establish the necessary general trial conditions at the particular location. Review the preparation for the test with all personnel involved. See that safety-relief valve discharge piping is secure. There must be at least two people present.

b. If possible, calibrated test gauges and thermometers should be temporarily installed to check the accuracy of the boiler pressure gauge and thermometer during the test.

c. Isolate the boiler from the rest of the heating system by closing the supply and return valves, if provided.

d. If an automatic water feeder is provided, the water inlet valve should be closed.

e. Shut the valve to the expansion tank. Drain all the water from the tank to ensure that an air cushion is provided. Open the valve to the tank. The expansion tank must not be isolated from the boiler during the pop test.

NOTE

Prepressurized expansion tanks do not require draining.

f. Drain all the water from the boiler through the safety-relief valve to reduce boiler pressure to not more than 50 percent of the safety-relief valve set pressure.

g. Place test leads across the appropriate terminals of the operating control to demonstrate the ability of the high-temperature cutout to function properly. After this has been checked, place test leads across the high-temperature cutout to permit continuous operation of the burner.

h. Make sure that all personnel are clear of the safety-relief valve discharge.

i. Observe that the pressure and temperature of the boiler water are rising. If an adequate air cushion is provided, the water temperature may rise to 274 °F in a system with a safety-relief valve set to open at 30 psig and as high as 370 °F in a system with a safety-relief valve set to open at 160 psig.

j. The safety-relief valve should open within an acceptable range below or above the set point. This is plus or minus 3 psig for valves set to open up to and including 60 psig, and plus or minus 5 percent of the set pressure for valves set to open above 60 psig.

k. The valve should open and discharge a mixture of water and vapor.

l. If the valve does not open between the allowable pressure tolerances described in Section 596.2j, it must be replaced with a new valve, returned to the manufacturer for repair, or field-repaired by the manufacturer.

m. If the valve does open satisfactorily, remove the test leads from the high-limit control. The valve will remain open and discharge water and steam until the closing pressure is reached. This may be 10 to 50 percent below the set pressure of the valve. There are no blowdown requirements for safety-relief valves.

n. After the safety-relief valve has closed, the remainder of the stored energy may be dissipated by slowly and carefully opening the boiler supply valve. The return valve may be opened after the pressures between the boiler and the supply systems have been equalized.

o. Allow the high-limit control to cycle the burner at least once to determine if it functions properly.

p. Remove the test leads from the operating control and allow it to cycle the burner on and off at least once to determine if it functions properly.

596.3 Capacity Test

A capacity test must be performed on safety-relief valves on all new boiler installations or on existing boilers when any modification changes the output of the boiler. They must also be made when the safety-relief valve is repaired or replaced. Hydrostatic (water pressure) testing is not an acceptable means of determining the capacity of a safety-relief valve. As with safety valves, the capacity of a safety-relief valve is measured in pounds of steam per hour or Btus per hour. Follow these procedures:

a. Establish the necessary general trial conditions at a particular location and review the preparation for the test with all personnel involved. If temporary piping is run from the safety-relief valve discharge, it must be properly secured in place to prevent whipping action during the test. At least two people must be present whenever such a test is being conducted.

b. It is recommended that calibrated test gauges and thermometers be temporarily installed to check the accuracy of the boiler pressure gauge and thermometers. It should be determined that all controls, gauges, etc., are designed to withstand the temperatures which will be experienced during this test.

c. Isolate the boiler from the supply and return piping by shutting respective valves. If a water feeder is provided that can feed water to the boiler during the test, it should remain operable.

d. Set the burner to operate at its maximum capacity. Ensure that combustion is complete with proper over-the-fire draft, cutting back on fuel supply if necessary to accomplish this. It would be advantageous to be able to meter the fuel flow to calculate the output of the boiler. On gas burners, this can be done by shutting off all other gas appliances in the building and using the gas and vapor. All personnel should keep clear of the end of the discharge pipe.

g. If the safety-relief valve does not open (flow equals 24 cu in/min) within its opening tolerances, or if the relief pressure exceeds that which is allowable, immediately shut down the burner and make the boiler inoperative until a new valve is installed and passes the tests as prescribed herein. For valves at pressures up to and including 60 psig, the pressure should not rise more than 6 psig above the set pressure. For valves at set pressures between 60 and 160 psig, the allowable pressure rise should be 10 percent at the set pressure.

h. If the valve opens within its opening tolerances, keep the burner running until maximum pressure is reached, unless the pressure exceeds those specified in Section 596.3g. If the maximum pressure is within acceptable limits, hold it there for 30 seconds to check for further rise. If there is no further pressure rise, shut down the burner by pulling test leads from the high-temperature cutout.

i. The safety-relief valve will continue to discharge until the blowdown pressure is reached. This may be 20 to 50 percent below the set pressure of the valve. This will vary because of difference in seat and disk design.

j. After the valve has closed, the residual steam in the boiler may be dissipated through the safety-relief valve by using the try lever or by slowly opening the stop valve in the supply line. After the supply valve has been opened wide, the return valve and valve in the piping to the expansion tank must be opened.

k. Allow the high-limit control to operate and shut down the burner at least one time to check its function. After this has been done, remove the test leads from the operating control and check to make certain it is functioning properly.

l. Enter all pertinent data in the log book.

CHAPTER 6

CENTRAL SYSTEMS FOR AIR-CONDITIONING

610 GENERAL

Central air-conditioning systems differ from self-contained or package-type air-conditioning units. In central air-conditioning systems, hot water or steam for heating and chilled water for cooling are produced at a central location and piped to the individual fan-coil units (referred to as air handlers). Air handlers are equipped with either a heating coil, a cooling coil, or both. In the central system, temperature, humidity, cleanliness, and air distribution are controlled to meet the requirements for the conditioned space. The air to be conditioned is either taken from outside the building, recirculated from the conditioned space, or supplied from both of these sources. From any source, the air to be conditioned is moved across either the cooling coil, the heating coil or, in some cases, both coils by the action of the fan.

620 TYPES OF CENTRAL AIR-CONDITIONERS

621 GENERAL

Four basic types of central air-conditioning are: all-air, air-water, all-water, and direct-expansion. Each type has its own functional and economic advantages and is designed for specific applications. Each name indicates the controllable medium that is supplied to the space to be conditioned.

622 ALL-AIR SYSTEMS

622.1 General

With the all-air system, the air-treating and refrigeration plants may be located in a central station some distance from the space to be conditioned. Only the final cooling/heating medium (air) is brought into the conditioned space through ducts and distributed within the space through outlets or mixing terminal outlets. Common names for some of the all-air systems are as follows:

a. Single-duct, variable volume

b. Single-duct, constant volume

c. Dual-duct

d. Single-duct with reheat

e. Multizone

f. Double-duct, constant volume

622.2 Single-Duct, Variable Volume System

This type of central system supplies a single stream of either hot or cold air at normal velocity. Volume is adjusted by automatic, thermostatically controlled dampers. (See Figure 6-1.)

622.3 Single-Duct, Constant Volume System

This type of central system supplies a single stream of either hot or cold air at constant volume. The layout of the system is the same as that shown in Figure 6-1, except for the absence of a static pressure regulator.

622.4 Dual-Duct System

This is a high-velocity system with a central air-conditioning plant supplying

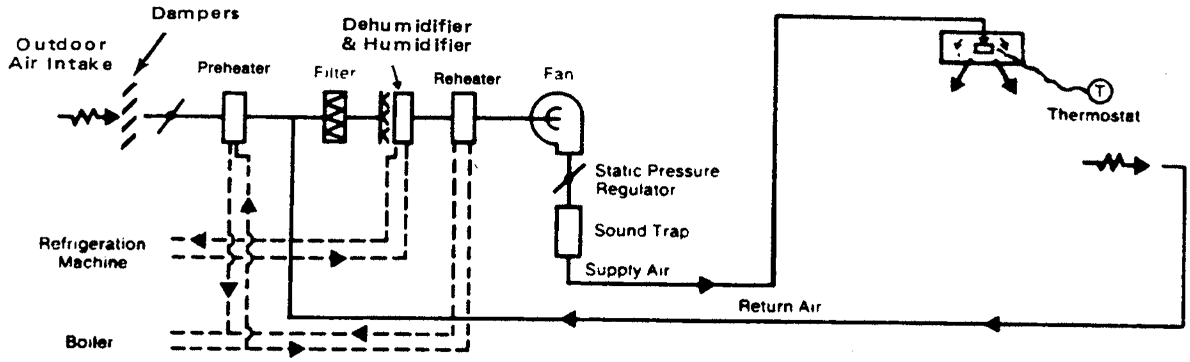


Figure 6-1
SINGLE-DUCT VARIABLE VOLUME SYSTEM

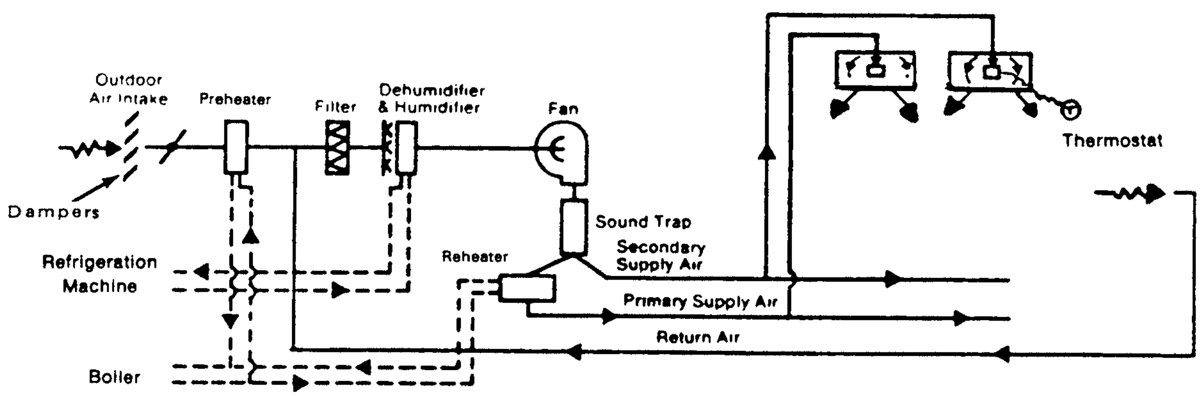


Figure 6-2
DUAL-DUCT SYSTEM

two air streams to each room. The primary air supply is constant-volume, variable temperature; the secondary supply is variable-volume, constant temperature adjusted by thermostatically controlled dampers. (See Figure 6-2.)

622.5 Single-Duct with Reheat System

This system consolidates all major equipment in the machine room except for the reheat element, which is located near the room or area to be conditioned. Primary treated air is supplied at constant volume from this central plant through a single duct to rooms. Each room is equipped with a small steam or hot-water coil, or a strip heater which is positioned either in the supply air stream or in an inducted-air position. (See Figure 6-3.)

622.6 Multizone System

This system distributes a single air stream to each room through ducts at

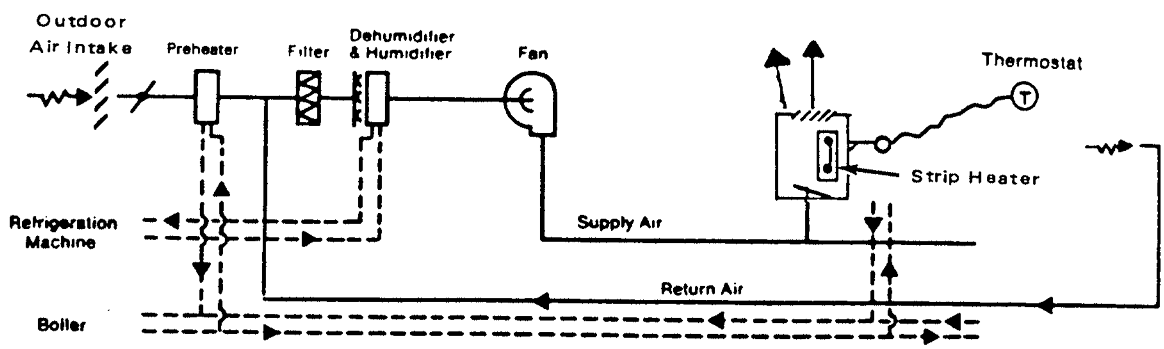


Figure 6-3

SINGLE-DUCT SYSTEM WITH REHEAT

normal velocity. Central air-treating apparatus includes dampers that premix the cold and warm air supplies controlled by the room thermostats. (See Figure 6-4.)

622.7 Double-Duct, Constant Volume System

This type of system supplies treated air through a pair of ducts to room

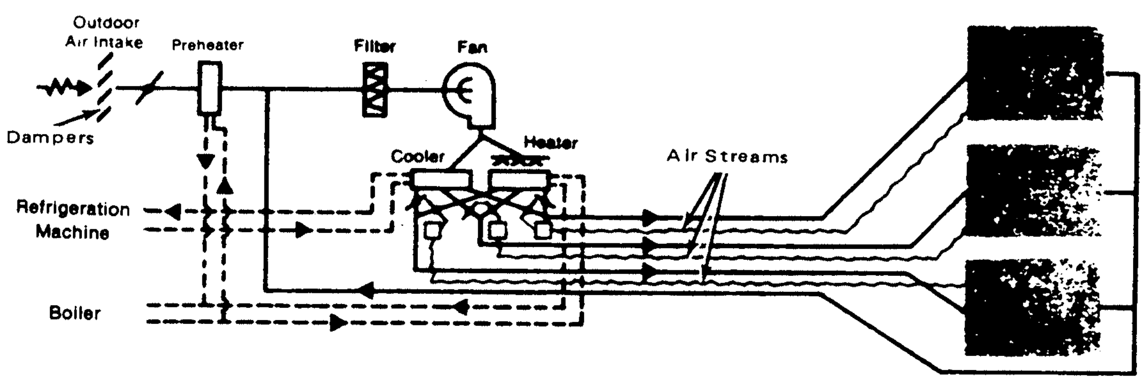


Figure 6-4

MULTIZONE SYSTEM

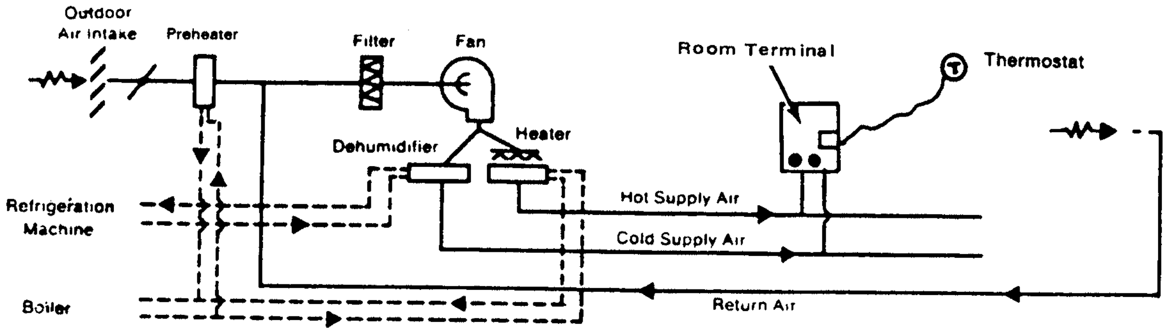


Figure 6-5
DOUBLE-DUCT CONSTANT VOLUME SYSTEM

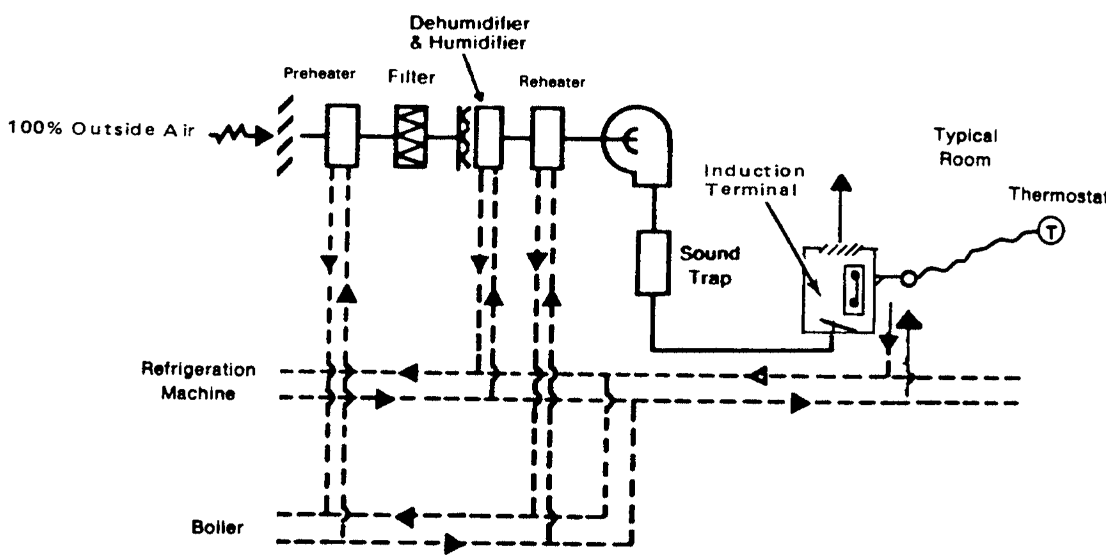


Figure 6-6
INDUCTION SYSTEM

terminals of special design and function. These terminals automatically mix air to maintain proper temperature and volume. (See Figure 6-5.)

623 AIR-WATER SYSTEMS

623.1 General

Like the all-air systems, the air apparatus and refrigeration plants are separate from the conditioned space. The cooling and heating to the conditioned space, however, is affected in only a small part by air brought from the central apparatus. The major part of the room's thermal load is balanced by warm or cool water circulated through either a coil in an induction unit or a radiant panel. The different air-water types are as follows:

a. Induction

b. Fan-coil with supplementary air

c. Radiant panels with supplementary air

623.2 Induction System

This system uses a high-velocity, high-pressure, constant-volume air supply to an induction terminal. Inducted air from the room is either heated or cooled within the terminal as required. Capacity control is accomplished by water flow or air bypass. (See Figure 6-6.)

623.3 Fan-Coil with Supplementary Air System

The fan-coil terminal provides direct heating or cooling of the room air. A supplementary constant-volume air supply provides the necessary ventilation. (See Figure 6-7.)

623.4 Radiant Panels with Supplementary Air System

Ceiling or wall, radiant-panel terminals provide radiant heating or cooling. A constant-volume air stream is supplied for dehumidification and ventilation. (See Figure 6-8.)

624 ALL-WATER SYSTEMS

The all-water systems are those with fan-coil room terminals connected to one or two water circuits. Chilled and hot water are supplied from a remote source and circulated through the coils in the fan-coil unit located in the conditioned space. Ventilation is accomplished by separate means. The various types of piping arrangements are discussed in Section 662.1.

625 DIRECT-EXPANSION SYSTEMS

In direct-expansion systems, liquid refrigerant from a remote condensing unit is piped to an evaporator coil in an air handler. These are usually referred to as DX coils and are used primarily in small systems (50 tons and less).

630 AIR HANDLERS

631 GENERAL

A basic air handling unit consists of the various components shown in Figure 6-9. To follow the air pattern, start with the outside air intake to the building. Outside air, or fresh air, is normally required in at least some minimum quantity to meet building codes during occupancy periods. The air passes through a normally closed outside air damper and mixes with the return air. This is mixed air supply. The air is then conditioned through any required filtering and passed through either the heating coil, cooling coil, or both. Discharge air from the supply fan then feeds all parts of the system.

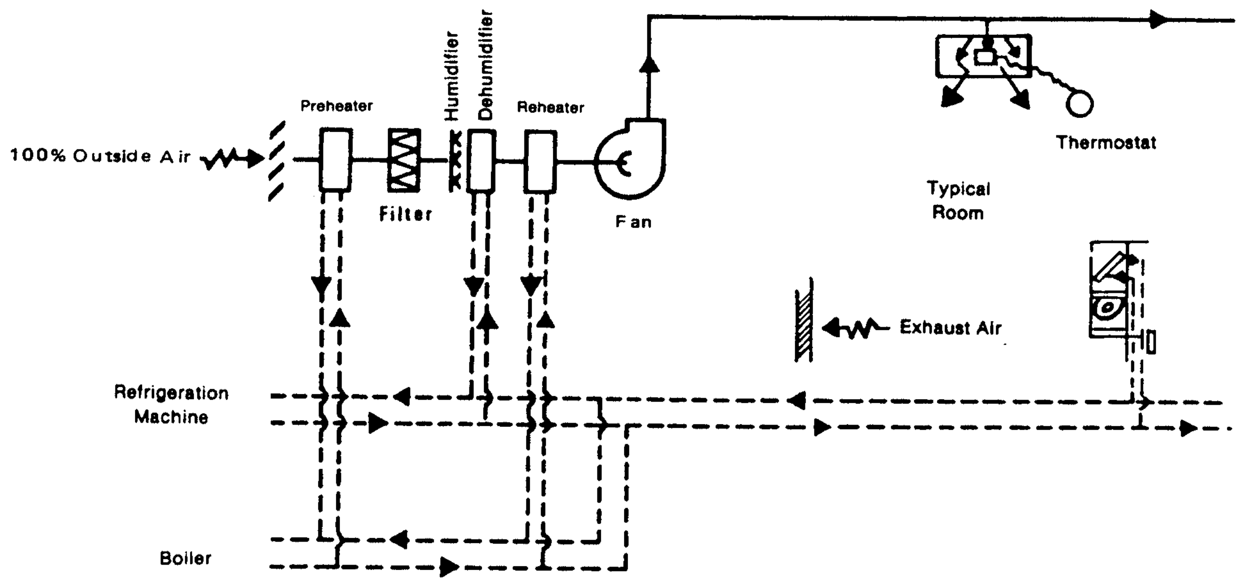


Figure 6-7
FAN COIL WITH SUPPLEMENTARY AIR SYSTEM

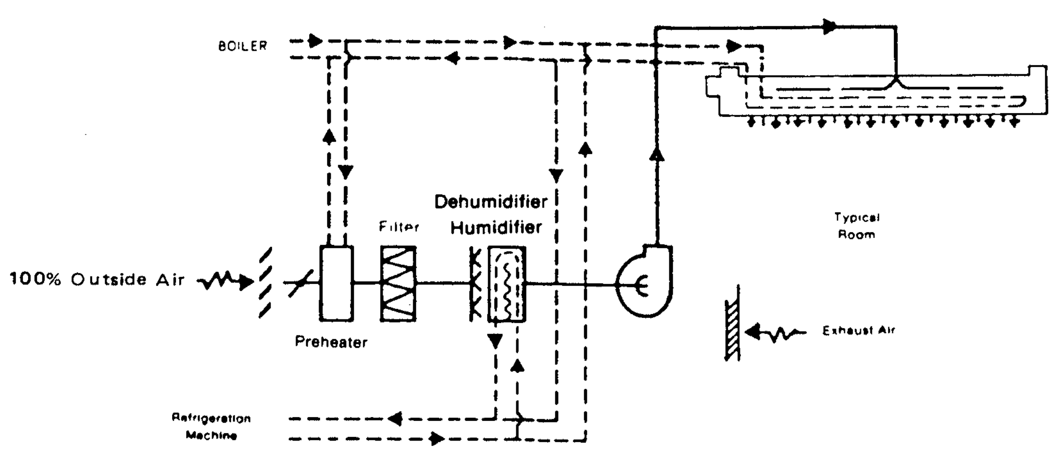


Figure 6-8
RADIANT PANELS WITH SUPPLEMENTARY AIR SYSTEM

If the system includes a return-air fan, air from the controlled space may be exhausted to the outside. In other instances, some or all of the return air may be routed through the return-air damper. The direction of the return air flow is determined by the mixed air controls that position the outside return and exhaust air dampers. The amount of exhaust air from a building is usually less than the outside air drawn in because of the desire to maintain a slightly positive pressure within the building. A slightly positive pressure is desired inside the building to help prevent drafts, heat gain or loss, and infiltration of dirt and dust from outside. Maintaining this positive pressure requires that consideration be given to the normal exfiltration of the building through doors, windows, cracks, etc.

632 TYPES

Four types of air handling units seen most frequently in postal facilities are as follows:

a. Single-zone with face and bypass dampers

b. Single-zone with sequenced valves and dampers

c. Multizone with discharge air controls

d. Dual-duct

632.1 Single-Zone with Face and Bypass Damper

.11 General. Approximately 60 percent of all air handlers used by the Postal Service are face and bypass damper systems. These are used for workroom floor areas in buildings designed prior to 1973. These units may have a cooling coil or both a cooling coil and a heating coil. Only the final control element (air) is brought into the conditioned space.

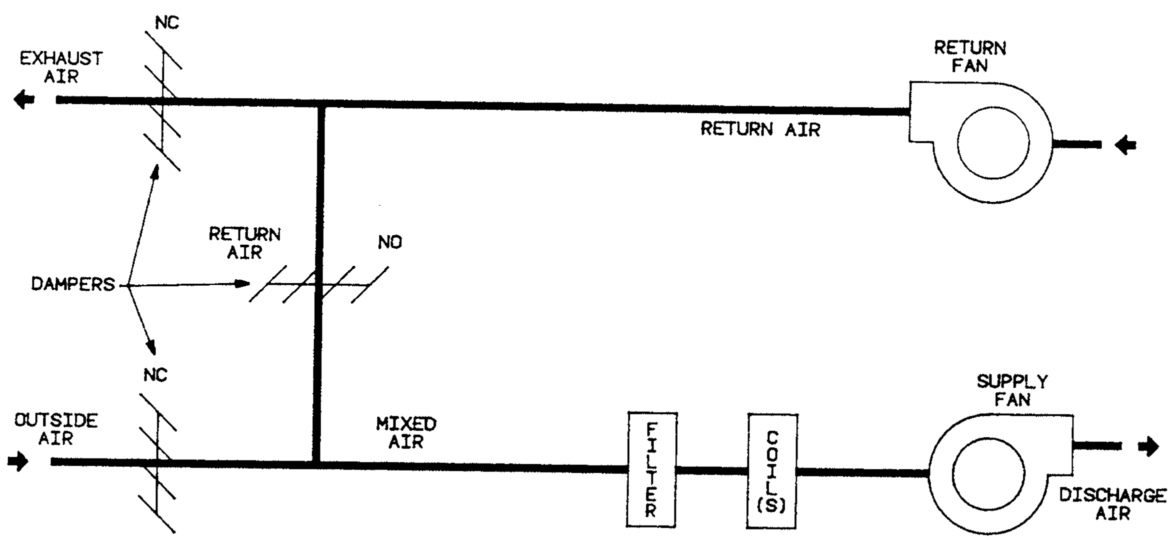


Figure 6-9

BASIC AIR HANDLING UNIT

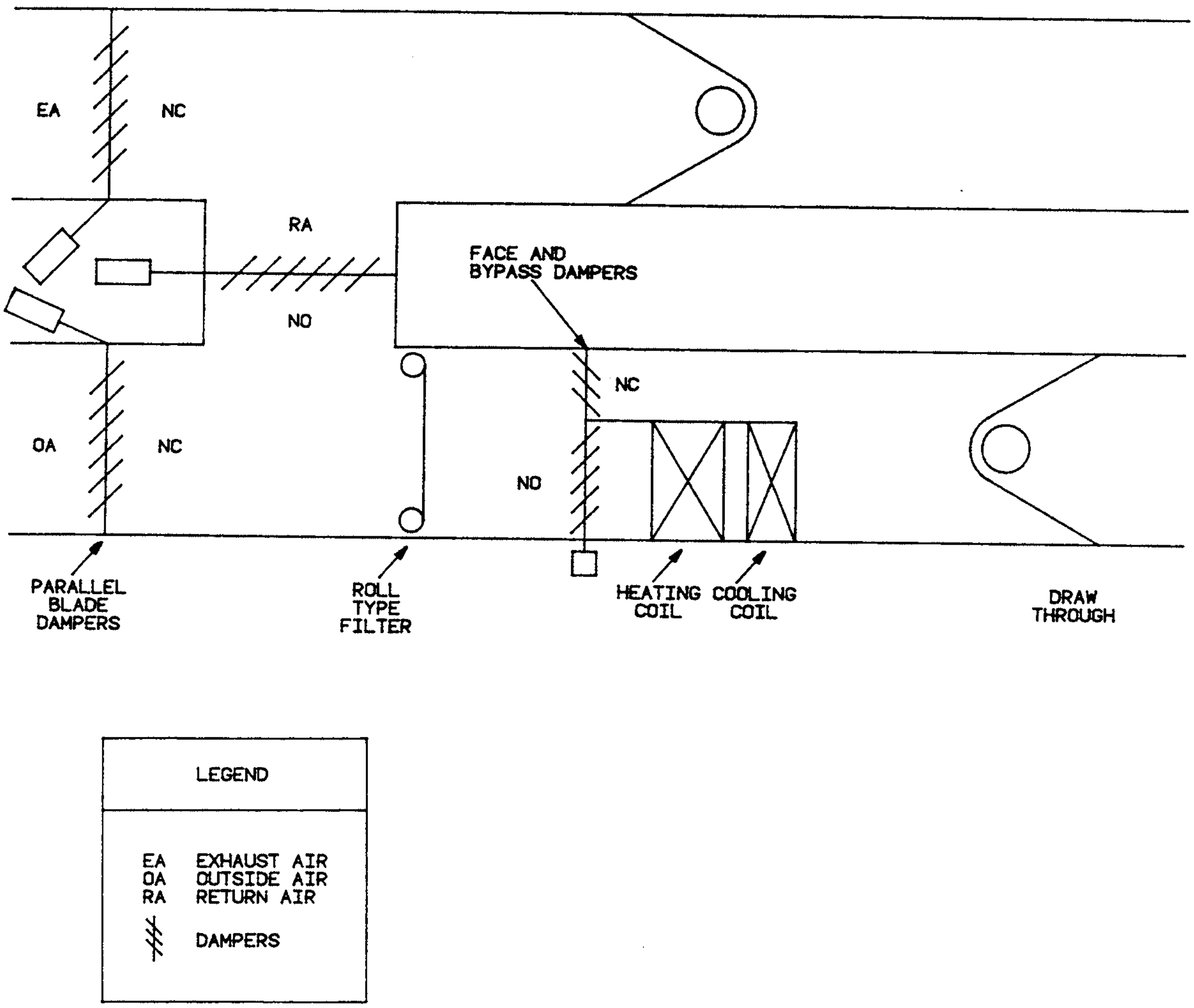


Figure 6-10

FACE AND BYPASS DAMPER SYSTEM

.12 Design Feature. The face and bypass damper system has a design feature that must be considered when troubleshooting its control system. The face dampers must close on a temperature rise during the heating season and must open on a temperature rise during the cooling season. This is accomplished by the use of two different control applications, a summer/winter thermostat or a direct-acting thermostat with a reversing relay and some type of switching device. Figure 6-10 illustrates the basic face and bypass damper system.

632.2 Single-Zone with Sequenced Valves and Dampers

The single-zone system with sequenced valves and dampers has replaced the face and bypass damper system in buildings designed after 1973.

Used for workroom floor applications, this air handler has a heating cycle, ventilation cycle, and cooling cycle operating in sequence. The heating valve is a normally open valve that closes on a temperature rise in the space. Following closure of the heating valve, outside air dampers start opening on a temperature rise in the space, providing the enthalpy limit controller allows for it. When temperature and humidity of the outside air prohibits its use for cooling, the outside air dampers close and the cooling valve begins to open. Figure 6-11 illustrates a typical sequenced valve and damper air handler.

632.3 Multizone with Discharge Air Control

The multizone air handler is used in office areas. The system distributes a single air stream to each room through ducts at a normal velocity. Central air-treating apparatus includes zone-controlled dampers that premix cold and warm air supplies controlled by room thermostats. System control design may incorporate outside air reset of a hot deck and a cold deck controller. Figure 6-12 illustrates a typical multizone air handler.

632.4 Dual-Duct

The dual-duct air handler is normally a high-velocity system with central air-conditioning being supplied in two air streams throughout the building. Room terminals, called mixing boxes, premix the cold and warm air supplies for each designated area. Rooms may have one or more mixing boxes depending on room size and use. Figure 6-13 illustrates a typical dual-duct air handler.

633 SCHEDULING, CYCLING, AND VARIABLE VOLUME

Air handlers should be scheduled to turn on or off as the work force changes in the building. Air handlers used to maintain mail processing areas should be secured during downtime.

Air handlers should be cycled on and off as the load changes. This cycling could be set up on intervals of 30 minutes on and 30 minutes off. Cycling should be developed in the "W" shape to control peak power usage.

See Part 648, Energy Management Systems.

Variable volume is an alternative to cycling. As the load decreases, variable vanes located on the blower intake close, causing the motor to unload. This operation use less amperage and is an energy saving feature.

634 FILTERS, COILS, AND BLOWER SECTION

The filters should be monitored on a daily basis. Inclined manometers or magnehelic gauges should be maintained to ensure accurate readings. Coils should be kept clean and the blower section checked for dirt or dust accumulation on fan blades. Chemical coil cleaners are available from several

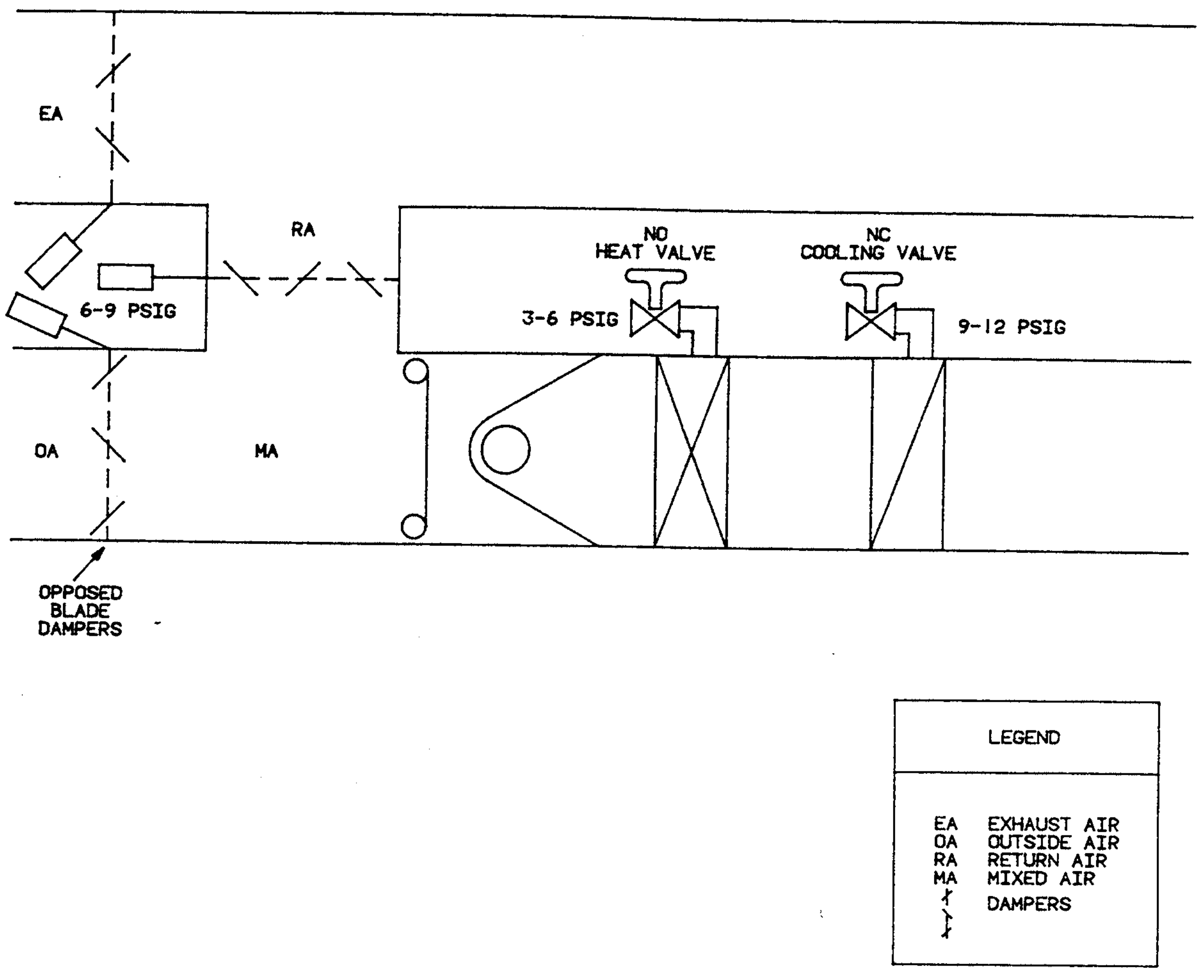


Figure 6-11

SINGLE ZONE WITH SEQUENCED VALVES AND DAMPERS

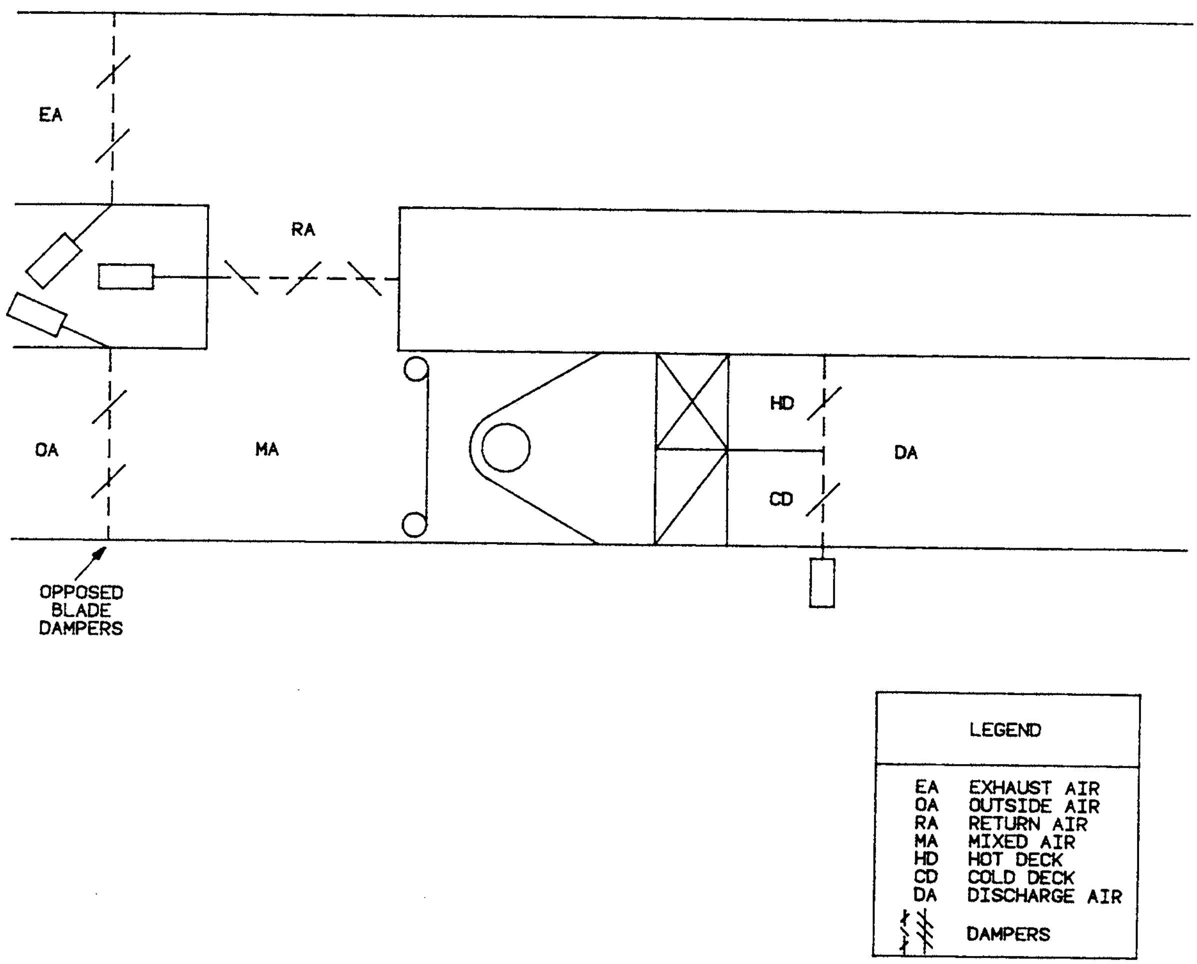


Figure 6-12
MULTIZONE WITH DISCHARGE AIR CONTROL

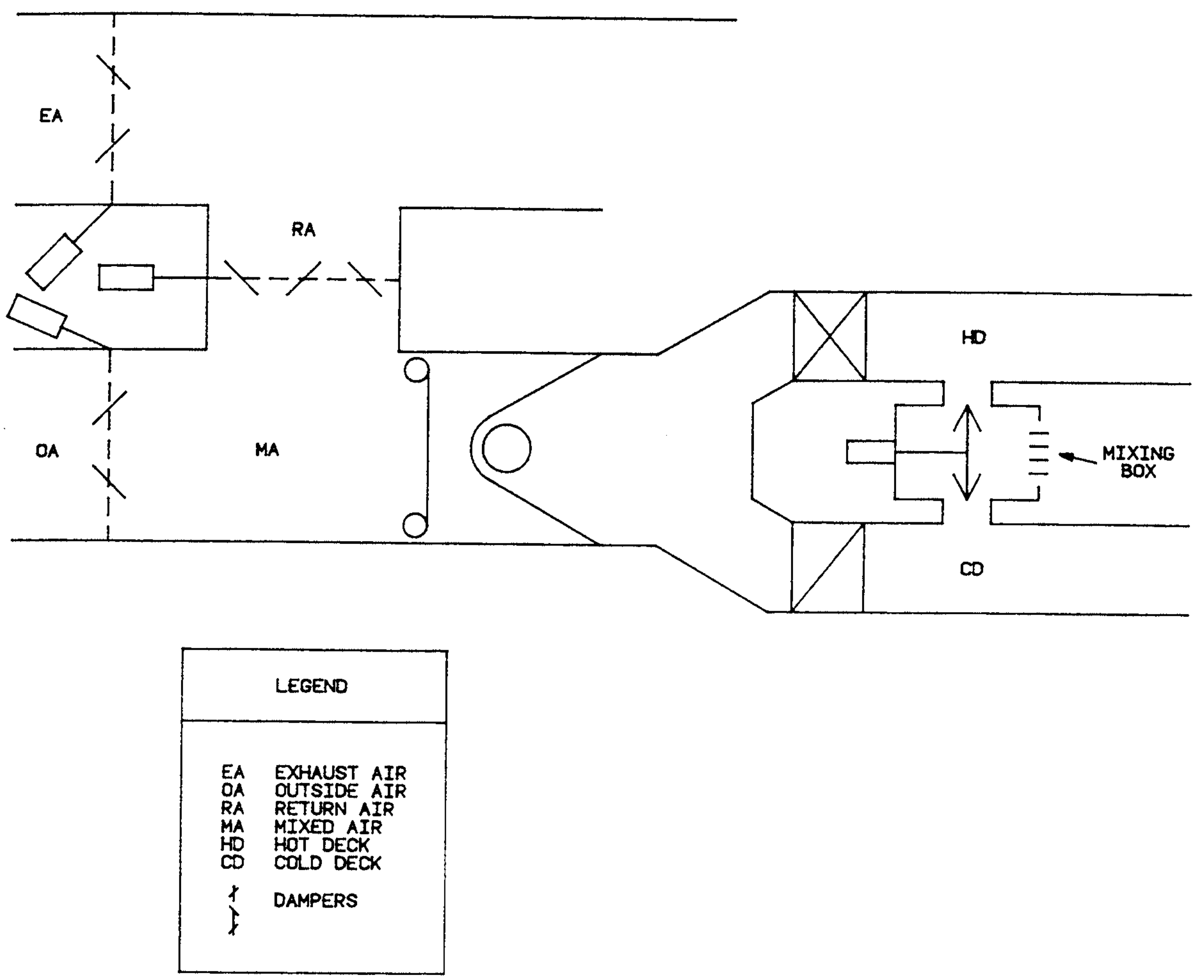


Figure 6-13

DUAL-DUCT AIR HANDLER

manufacturers. Caution should be used when applying coil-cleaning chemicals. Upon completion of cleaning, coils should be checked with a manometer for an indication of airflow through all passes of the coil.

635 FILTERS

635.1 Roll-Type Filters

At present, glass fiber, noncleanable, roll-type filters are the predominant type of filter installed in postal air handlers. Advanced technology has allowed for the development of tacktified, dual-ply, polyester filter media. These media, which have a greater density than glass fiber, eliminate much of the pull-through. Roll-type filters must function properly in the air handler mechanisms and provide adequate dust trapping and holding capacity. These filters must meet the requirements of Federal Specification F-F-1658 dated September 14, 1973. Paragraph 3.2 of the specification requires the testing and qualification of filters every 2 years. The manufacturer should furnish certification that the filter has been tested and is on the qualified products list. A copy of the USPS Automatic Roll Filter Performance Summary is shown in Exhibit 6-1. Movement of the filter is automatically controlled by an advancing mechanism such as follows:

a. Timer. Advances the filter media in increments at a predetermined rate.

b. Pressure Switch. Advances the filter media when the buildup of dust causes a pressure drop across the media that exceeds a set value. The pressure range is usually between 0.30 and 0.45 of an inch of water.

c. Timer and Pressure Switch. Operates as described in Section 635.1a. However, a pressure switch overrides the timer if an unusually dusty condition causes the pressure drop to exceed the set value before the timer calls for advancement of the media.

d. Photocell Advance Switch. The photocell has been adapted to filter systems as an advance mechanism. With a light bulb in the return air plenum and the photocell placed after the filter, the filter is advanced as the light fades.

635.2 Sectional Throw-Away Filters

When dirty, these should be removed, discarded, and replaced. They may be vacuum-cleaned ONLY in an emergency, and used only until a replacement is available. When not available locally, postmasters should try to obtain them through the refrigeration service contractor (if the local office has such a service contract) or through the assistance of a larger, nearby post office. (A copy of the Performance Summary for Disposable Filter Panels is shown in Exhibit 6-2.)

635.3 Sectional Cleanable Filters

These should be washed in a solution of mild detergent and water. A supply of spare filters should be kept on hand so that the air handlers need not be shut down while the filters are being cleaned. For installations with a large number of filters, a contract for cleaning and servicing should be considered. Clean, efficient filters are necessary to remove dust, lint, and other foreign material from the air, as well as to ensure efficient transfer of heat between the heating or cooling coil and the air as it is blown across the coils. Where air is found to bypass a filter because of poor installation, necking, or holes in the filter, the condition should be corrected immediately. Failure to do so can result in a clogged or frozen coil and unwarranted, additional expenses incurred to clean or replace the coil.

CAUTION

Under no circumstances may air handlers be operated without filters or while changing filters.

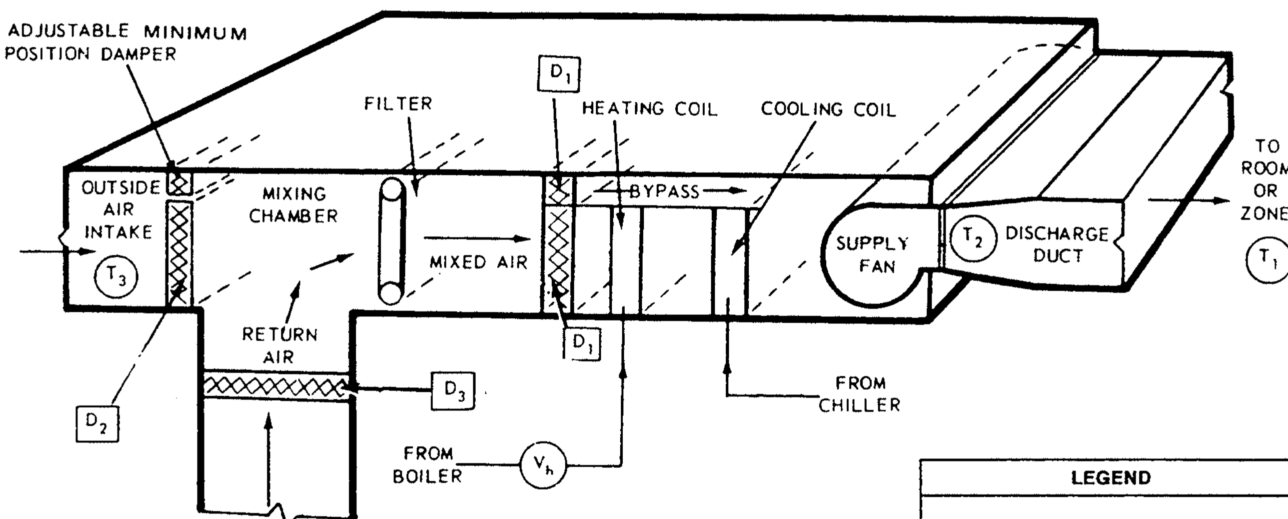
636 OPERATION

636.1 General

The single-zone air handler (see Figure 6-14) will be used as an example to explain in detail how the temperature of the air leaving the discharge duct of the unit is automatically controlled.

636.2 T_1-T_2 Relationship

For each room or zone served by an air handler, there is a specific T_1-T_2 relationship based on the design requirements for that particular room or zone. Assume a T_1-T_2 relationship for a typical zone as follows:



LEGEND	
D_1	Face and Bypass Damper
D_2	Fresh Air Intake Damper
D_3	Return Air Damper
V_h	Three-Way Mixing Valve
T_1	Room Thermostat
T_2	Submaster Thermostat
T_3	Outside Limit Thermostat

Figure 6-14

TYPICAL SINGLE-ZONE AIR HANDLER

TABLE 6-1

T_1-T_2 TEMPERATURE RELATIONSHIP

T_1 Room Temperature	T_2 Discharge Temperature
72 °F	85 °F
74 °F	75 °F
76 °F	65 °F

This relationship was originally determined at the time of design and was supposed to have been checked during installation so that the final table shown on the drawing furnished for a particular fan-coil unit (air handler) should be correct.

636.3 Application of T_1-T_2 Relationship

Assume the system is operating in the heating cycle and the outside temperature is lower than 55 °F. The set point for the zone is 74 °F and the same T_1-T_2 relationship applies as shown in Table 6-1. Now assume the temperature in this zone has risen to 75 °F. The T_2 submaster thermostat then positions the face and bypass dampers D_1 by gradually closing the face damper serving the heating coil and gradually opening the bypass damper serving the bypass deck. This produces a discharge temperature at T_2 of 70 °F. If the temperature continues to rise, to 76 °F for example, the face damper to the heating coil fully closes and the damper to the bypass deck fully opens to produce a discharge temperature at T_2 of 65 °F.

636.4 Fresh Air for Cooling

Handbook MS-49, Energy Conservation and Maintenance Contingency Planning, requires that outside air be used for cooling when it is suitable. Enthalpy controls have been installed at many locations to achieve this. When air-conditioning or heating is required, however, keep fresh air to a minimum to prevent unnecessary heating and/or cooling load. Maintain fresh-air dampers to control leakage and adjust them so that minimum outside air is obtained. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Standard 621981, provides guidance on the minimum acceptable levels of outside air. A copy of this standard is available from the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329-2305.

636.5 Fresh-Air Intake Damper D_2

.51 Purpose. This damper, when provided, is always open to its set position when the fan is operating and is always closed when the unit is not operating. It provides the minimum amount of fresh air necessary to offset infiltration.

NOTE

Where no minimum-position damper has been provided (usually in older installations), the fresh-air intake damper serves this purpose. The fresh-air intake damper is activated by the T_2 submaster thermostat when the action of the bypass damper D_1 is not sufficient to maintain the zone temperature at design or set conditions.

.52 **Example.** Take the same example given in Section 643.74 and assume that the temperature in the zone has now risen above 65 °F. The T_2 submaster thermostat will not gradually open the fresh-air intake damper D_2 but will cause the return-air damper D_3 to gradually close until the set temperature in the zone is satisfied. If the zone then cools off, the dampers will begin to act in reverse.

.53 **Minimum Position.** When the fresh-air intake damper D_2 also serves as the minimum-position damper, it is closed when the unit is not operating. When the fan is turned on, the damper automatically opens to its set minimum position and remains in that position until actuated by the T_2 submaster thermostat as described in the preceding example.

636.6 Return-Air Damper (D_3)

This damper is normally closed when the unit is not operating. When the fan is turned on, the damper automatically assumes its set position. It remains in the position until actuated by the T_2 submaster thermostat in conjunction with the outside fresh-air intake damper D_2. As damper D_2 gradually opens, as described in Section 643.75, the return-air damper D_3 gradually closes. When D_2 is wide open, D_3 is fully closed.

636.7 Mechanical Cooling Cycle

Assume the system is providing cooling instead of heating and the plant is being operated on the mechanical cooling cycle instead of the heating cycle used for the example in Section 643.74. This means that the refrigeration plant is being operated and chilled water is circulating through the cooling coil in the air handler. When operating thus, the face and bypass dampers perform in the same manner as described in Section 643.75 to hold the temperature in the zone at the set point. In the case of cooling, thermostat T_3 causes the outside fresh-air intake damper to return to its minimum opening whenever the outside temperature exceeds a set point.

636.8 Ventilation Cycle

Operation under this cycle, when neither heating nor mechanical cooling is required, is accomplished through the T_1-T_2 relationship in the same way as described in the two previous examples. The only difference is that there is no hot water in the heating coil or chilled water in the cooling coil. Thus, all effective control would be through the fresh-air intake damper D_2 as it is actuated by the submaster thermostat T_2 from signals received from the zone thermostat T_1.

637 HOT-WATER TEMPERATURE CONTROL

637.1 General

For installations using a hot-water coil (rather than a steam coil), the temperature of the water circulating through the heating coil is varied in accordance with the outside temperature through the use of an outside control and a three-way water-mixing valve.

637.2 Outside Control

The outside control activates a water-mixing valve whereby the amount of water taken from the boiler is mixed with the return water to produce a circulating-water temperature inversely proportional to the outside temperature. This means that the higher the outside temperature, the lower the temperature of the circulating water in the heating coil, and the lower the outside temperature, the higher the circulating-water temperature.

637.3 Three-Way Mixing Valve V_h

This water temperature change is accomplished through a three-way mixing

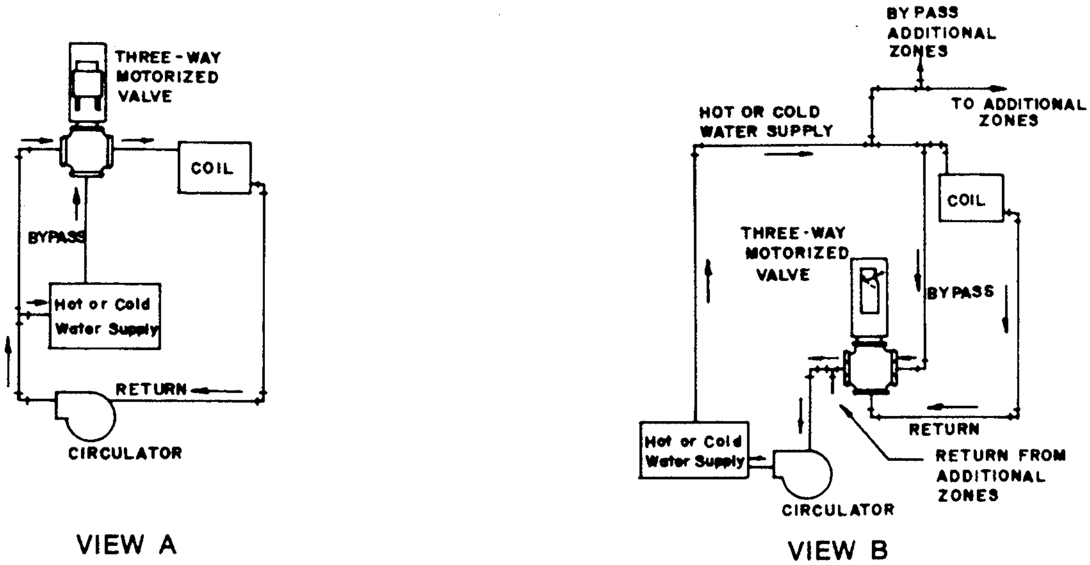


Figure 6-15

TWO METHODS OF PIPING THREE-WAY MIXING VALVES

valve. The valve is so constructed that it can take water directly from the boiler (usually 190 to 210 °F) and circulate it directly to the heating coil, mix it with return water in any proportion, and circulate the mixture through the coil or circulate only return water through the coil. (See Figure 6-15.) The valve is completely closed off to the boiler at an outside temperature of 65 °F and completely open to the boiler at an outside temperature of 0 °F.

637.4 Water Temperature Relation Table

In the design stage, heating plant capacity is based on the outside design temperature, taking into account the lowest temperature on record for a locality. In actual operation, the temperature at which the boiler water is maintained is an additional factor. For the operator of a heating plant to determine that the heating plant and related controls are operating properly, temperature relation tables are furnished. Table 6-2 (A, B, and C) show the relationship between outside temperature and the corresponding temperature at which the water should be leaving the mixing valve. Table 6-2A is based on a boiler water temperature maintained at 190 °F, Table 6-2B is based on for a temperature of 200 °F, and Table 6-2C is based on temperature of 210 °F. Each table is designed for the three most commonly used design temperatures, namely -10 °F, 0 °F, and +10 °F. To see if the heating plant and controls are operating properly, an operator determines the design temperature for the installation, selects the proper boiler water temperature table, and then checks the temperature of the water leaving the mixing valve.

638 MAINTENANCE OF AIR HANDLERS

Preventive maintenance is the route to energy management. Mixed air plenums should be kept clean. Dust, dirt,

TABLE 6-2

WATER TEMPERATURE RELATION TABLE

A. 190 °F Boiler Water

Outside Temperature	Temperature of Water Leaving Mixing Valve		
	Design Temperature -10 °F	Design Temperature 0 °F	Design Temperature +10 °F
Above 65 °F	Circulating pump off. No water flowing.		
65 °F	80 °F	80 °F	80 °F
60 °F	88 °F	89 °F	90 °F
55 °F	95 °F	97 °F	100 °F
50 °F	102 °F	106 °F	110 °F
45 °F	110 °F	114 °F	120 °F
40 °F	117 °F	122 °F	130 °F
35 °F	124 °F	131 °F	140 °F
30 °F	131 °F	139 °F	150 °F
25 °F	139 °F	148 °F	160 °F
20 °F	146 °F	156 °F	170 °F
15 °F	153 °F	164 °F	180 °F
10 °F	161 °F	173 °F	190 °F
5 °F	168 °F	181 °F	--
0 °F	175 °F	190 °F	--
-5 °F	183 °F	--	--
-10 °F	190 °F	--	--

TABLE 6-2 (Continued)

WATER TEMPERATURE RELATION TABLE

B. 200 °F Boiler Water

Outside Temperature	TEMPERATURE OF WATER LEAVING MIXING VALVE		
	Design Temperature -10 °F	Design Temperature 0 °F	Design Temperature +10 °F
Above 65 °F	Circulating pump off. No water flowing.		
65 °F	80 °F	80 °F	80 °F
60 °F	88 °F	89 °F	90 °F
55 °F	96 °F	99 °F	102 °F
50 °F	104 °F	108 °F	113 °F
45 °F	114 °F	118 °F	125 °F
40 °F	120 °F	126 °F	134 °F
35 °F	128 °F	135 °F	145 °F
30 °F	136 °F	145 °F	156 °F
25 °F	144 °F	154 °F	167 °F
20 °F	152 °F	163 °F	178 °F
15 °F	160 °F	172 °F	189 °F
10 °F	168 °F	181 °F	200 °F
5 °F	176 °F	190 °F	--
0 °F	184 °F	200 °F	--
-5 °F	192 °F	--	--
-10 °F	200 °F	--	--

TABLE 6-2 (Continued)

WATER TEMPERATURE RELATION TABLE

C. 210 °F Boiler Water

Outside Temperature	TEMPERATURE OF WATER LEAVING MIXING VALVE		
	Design Temperature -10 °F	Design Temperature 0 °F	Design Temperature +10 °F
Above 65 °F	Circulating pump off. No water flowing.		
65 °F	80 °F	80 °F	80 °F
60 °F	89 °F	90 °F	92 °F
55 °F	98 °F	100 °F	103 °F
50 °F	106 °F	110 °F	115 °F
45 °F	115 °F	120 °F	127 °F
40 °F	123 °F	130 °F	139 °F
35 °F	132 °F	140 °F	150 °F
30 °F	141 °F	150 °F	162 °F
25 °F	150 °F	160 °F	174 °F
20 °F	158 °F	170 °F	186 °F
15 °F	167 °F	180 °F	198 °F
10 °F	176 °F	190 °F	210 °F
5 °F	184 °F	200 °F	--
0 °F	193 °F	210 °F	--
-5 °F	201 °F	--	--
-10 °F	210 °F	--	--

pollen, and mold spores tend to collect in the plenum where outside air and return air are mixed, resulting in an unhealthy situation. Dirty filters allow pull-through causing a dirt buildup on the blowers and the coils. This buildup can reduce efficiency by as much as 70 percent. A sample preventive maintenance checklist for supply/return fans and associated equipment is shown in Exhibit 6-3. Information on care and adjustments of belts and bearings is in HBK MS-43, General Maintenance for Mail Handling Equipment.

640 AIR-CONDITIONING CONTROLS

641 DEFINITIONS

The basic air-conditioning cycle control is a device that starts, stops, regulates, and/or protects the heating and cooling systems and their components. It does this by sensing and measuring changes in the heating or cooling medium (air or water). The impulse received from a sensing and measuring device meters the energy used in the control circuit. The metered energy actuates the control equipment which then initiates a change or prevents a further change in the heating or cooling medium. Abbreviations necessary to understand automatic controls are listed in Table 6-3; terms necessary to understand automatic controls are defined in the glossary that follows.

absolute pressure. Gauge pressure plus atmospheric pressure (14.7 psi).

actuator. A device that moves or stops the operation of the conditioning equipment in response to changes in branch line pressure of a controller.

air control damper. A device used in central fan systems to control the mixture of air admitted to the system. Installed in the fresh air intake, return air and exhaust ducts.

air motion relay. A device used to sense suction and/or discharge pressures across a coil or fan.

ambient temperature. Temperature of air or fluid that surrounds objects on all sides.

authority. The adjustment that determines the effect of a secondary transmitter input signal on the branch pressure output of a receiver controller as compared to the effect of the primary transmitter input signal.

auxiliary device. A device in an automatic control system that is not an automatic control, such as an air compressor, transformer, or thermometer.

averaging element. Normally used for duct control when there is a large temperature gradient across the duct.

averaging relay. Used where the application requires operation of a final control device or setting a controller by the average signal from two or more controllers.

ball valve bleed. An arrangement that varies the exhaust stream by positioning a small ball in a shaped opening. This increases output pressure linearity and produces a significant amount of internal feedback.

branch lines. Pneumatic control system air lines in which a varying air pressure is maintained by the action of controllers. The air pressure positions valves, dampers, or similar devices.

British Thermal Unit (Btu). The amount of heat required to raise the temperature of 1 pound of water 1 ^{o}F.

calibration point. The set point at which a control is calibrated. Normal calibration; 9 psig in branch line when ambient temperature equals set point.

capacity index (Cv factor). The quantity of water in gallons per minute at 60 °F that will flow through a given valve with a pressure drop of 1 psig.

cfm. Air quantity in cubic feet per minute. One cubic foot equals 1,728 cubic inches.

cim. Air quantity in cubic inches per minute.

close-off. The close-off rating of a valve is the maximum allowable pressure drop to which the valve may be subjected while fully closed.

compensated control. A method of control in which the set point of one controller is automatically changed as the conditions at another control point change.

constant volume control. Used primarily for the control of total airflow from mixing units used in high-pressure, high-velocity dual-duct air distribution systems.

control point. The condition actually being maintained by a controller.

controllers. Devices that measure changes in temperature, pressure or humidity content, and position actuators to make adjustments to counteract the change.

corrective action. Action that results in a change in position of the operating device.

critical pressure drop. Fluid flow through a valve increases with increased pressure drop until a critical value is reached. Any drop in excess of this value can cause noise and wear.

cycling. The periodic change in the medium to be controlled from one value to another.

cycling-hunting. The periodic changing of the controlled variable above and below the set point.

day/night thermostat. A pneumatic thermostat that can be indexed to control at one temperature during day operation and another temperature at night.

desired value. The value of the condition of the medium at which the medium is to be maintained (under ideal conditions desired value would be equal to the set point).

deviation. Departure of the control point from the set point or the amount of that departure.

differential. Applies to two-position controllers. The change in the controlled condition necessary to cause the controller to move from one extreme of its travel to the other.

differential pressure control. A controller that measures and controls the difference between two separate pressures.

direct acting (D.A.). The action of a controller that increases its branch line pressure in response to a rise in temperature.

direct-acting actuator assembly. An actuator that extends with increasing pressure.

direct-acting valve assembly. Valve assembly in which the valve plug is pushed down to close off the flow and raised to open.

direct bleed leakport. An assembly within a pneumatic controller which incorporates a flat lever positioned in the exhaust stream of a flat-tipped nozzle. This produces a nonlinear output with negligible feedback.

diverting relay. Normal function is to divert air pressure either from one supply to one of two branch lines or from one of two supply lines to one branch line. Also, some types can convert proportional pressure signals to positive pressure changes or to feed and exhaust branch lines.

diverting valve. A three-way valve which has one inlet and two outlets. It can direct the full flow to one outlet or proportion the flow between the two outlets.

double-seated valve. Fluid pressure is introduced between the two seats enabling the valve to close against high pressure. Should not be used when tight shutoff is required.

dry-bulb temperature. Air temperature as indicated by an ordinary thermometer.

dual thermostat. A two-temperature thermostat. Equivalent to two separate thermostats in one case each with a different set point.

electric/pneumatic relay (EP). An electrically operated diverting valve designed for diverting air from one controller to another.

enthalpy. Term used for airstream total heat content. It is expressed in Btus.

equal percentage. Each equal increment of opening increases the flow by an equal percentage over the previous valve.

feedback. A design feature of some pneumatic controls that provides a true proportional relationship between the movement of a sensing element and the output air pressure variation it produces.

firestat. A control used in return air-duct system to shut down air-conditioning or ventilating fans when air temperature goes above a preset limit.

fpm. Air velocity in feet per minute.

freezestat. A control used to protect against freezeup of heating or cooling coils or similar temperature applications.

gpm. Water flow in gallons per minute.

gradual switch. Pneumatic manual switches for adjusting the air pressure in a line to any value from zero to main air pressure.

high limit. Prevents operation of equipment when it would cause dangerous or undesirably high temperature pressure or relative humidity.

humidity control. A device which measures and controls the moisture content of air.

insertion thermostat. Controllers with extended elements which can be inserted into a duct or other enclosure in which temperature is to be maintained.

limit control. Controllers used in a control system to keep the temperature, pressure, or relative humidity in a duct within a preset limit.

linear. A characteristic of flow through a valve whereby the opening and flow are related in direct proportion.

mains. In pneumatic-control systems, mains are air lines carrying air at a constant supply pressure, usually 15 to 25 psig.

master controller. A controller that measures conditions at one point and resets the set point of another controller.

mixing valve. A three-way valve which has two inlets and one outlet. The valve is constructed with one disc between two seats. It mixes two fluids in controlled proportions and directs the mixture to the common outlet.

motorized damper. Consists of a damper to which a pneumatic actuator is connected. It is possible to mount the actuator so that the damper is either normally open or normally closed.

motorized valve. A pneumatic valve consisting of the actuator and the valve body.

normally closed (NC). A controlled device that moves toward the closed position as the branch line pressure decreases is considered normally closed.

normally open (NO). A controlled device that moves toward the open position as the branch line pressure decreases is considered normally open.

offset. The shift in control point which occurs in all proportional control systems.

pilot bleed relay. A relay system in some pneumatic controllers that translates the movement of the sensing element into a changing pressure to be fed to the actuator.

pneumatic actuator. A standard pneumatic actuator moves toward the advanced position as the branch line pressure increases and toward the retarded position as the branch line pressure decreases.

pneumatic/electric relay (PE). An air-actuated device used to make or break electrical contacts in connection with the operation of the control system.

positive-acting. In pneumatic-control devices this is an abrupt change in the branch line pressure of a controller from 0 to 15 psig. This causes either a fully open or fully closed condition.

positive-positioning relay. An auxiliary device which can be fitted to a damper or valve actuator. It can position the actuator accurately in response to signal pressure from the controlling instrument, regardless of the load.

pressure drop. The amount of pressure lost between any two points in a system.

primary element. The portion of the control that first uses energy derived from the controlled medium. For example, a thermostat bimetal is a primary element.

proportioning control. A mode of control in which the controlled device may assume any position from fully closed to fully open.

quick opening. A characteristic of flow through a valve whereby the maximum flow is approached rapidly as the device begins to open.

receiver-controller. A device that converts a main air supply into a varying 3 to 15 psig output in response to a varying 3 to 15 psig input signal from one or more external devices.

relative humidity. The ratio of the amount of water vapor present in air to the greatest amount possible at the same temperature.

remote-bulb thermostat. A thermostat having an element in the form of a liquid- or vapor-filled bulb connected by flexible capillary tubing to a bellows or diaphragm.

reset control. A device which can have its set point changed automatically by a second controller because of changes in temperature, pressure, or humidity.

restrictor. In pneumatic control systems this device is used to maintain a constant supply pressure to transmitters.

reverse acting (R.A.). The action of a controller that decreases its branch line pressure in response to a rise in temperature.

reverse-acting actuator assembly. An actuator that retracts with increasing pressure.

reverse-acting valve assembly. Valve assembly in which the valve plug is raised to close off the flow and pushed down to open.

reversing relay. This device is used to reverse a proportional signal from a controlling device.

selector relay. These relays are used where the application requires the comparison, selection, and transmission of one of two proportional signals.

self-contained control. A control that has the source of power, sensing element, and final control mechanism contained within a single instrument.

sensitivity. The ratio of the rate of controller response to each unit of change of the controlled variable. Example: In a pneumatic thermostat, sensitivity is the psi change in control air presssure for each degree of temperature change felt by the sensing element.

set point. The temperature, relative humidity, or pressure to be maintained and at which the controller is set.

single-seated valve. Used for tight shutoff but should not be used where high differential pressures exist.

single-unit control. An automatic conditioning systems regulated by a single thermostat.

span. Generally the difference between the lowest possible set point and the highest possible set point of a temperature controller or transmitter. Example: a 40 to 240 ^{o}F device has a 200 ^{o}F span.

static pressure. The outward push of the air against the duct walls.

submaster controller. A controller that is automatically set by a master controller as the condition changes at the master controller.

summer/winter. A term that designates a controller or control system for year-round heating/cooling control.

surface thermostat. A device designed for mounting on and measuring the temperature of a surface such as that of a pipe.

throttling range. The amount of change in the controlled variable required for the controller to move the controlled device from one extreme to the other, its complete stroke.

transmission. Modern pneumatic-control system designed around controllers that have had their functions of sensing and controlling split into separate devices connected by a transmission line air piping.

transmitter. A pneumatic transmitter measures air or fluid temperatures and transmits a 3 to 15 psig signal to a controlling and indicating device.

two-position control. A method of control in which the final control element is either on or off.

vacuum pressure. Pressure below atmospheric pressure.

volume (booster) relay. A device used to amplify the volume of control air and minimize system transmission lag.

wet-bulb temperature. Air temperature indicated by a thermometer with a wet wick. As the moisture from the wick evaporates, the air will be slightly cooler than a dry-bulb reading in the same area.

zone control. An area being controlled that is divided into two or more zones. Each zone has its own individual thermostat.

642 TYPES OF CONTROL SYSTEMS

A variety of control systems are used with chiller, boiler, and air handler installations. Control systems may be electric, electronic, or pneumatic (using compressed air). Another way of classifying automatic control systems is by defining their action as two-position, floating, or proportional. Two-position control provides full-on or full-off operation of the controlled device with no intermediate positions. Floating controls position the controlled service device as required to maintain room conditions at the control set point. They also permit the operator to stop at any position between full-on and full-off. With proportional control, the controlled unit assumes a position proportional to the change in room conditions. Proportional action is accomplished through feedback linking the controlled unit to the sensing unit. If automatically controlled, these units may include sensing devices, relays, motor-operated valves, or timing devices. Examples are thermostats, humidistats, aquastats, ductstats, water-control valves, and solenoids. The majority of USPS installations use electronic controls in conjunction with pneumatically operated valves or damper motors. The simplest automatic control system uses a sensing device and an operating device; a complex control system is a combination of the two.

643 ELECTRONIC CONTROLS

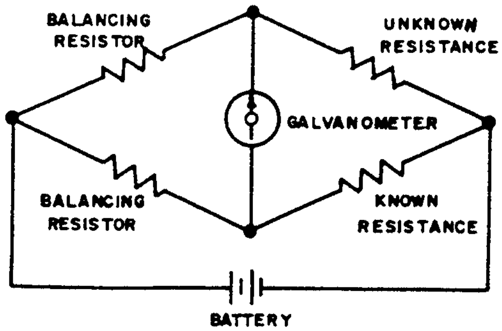
643.1 Description

Electronic controls use a coil of wire, located in an appropriate enclosure in the room or medium being controlled, as a sensing element. A two-wire connection to the coil completes a low-voltage circuit to other electronic components. The electrical resistance of any wire changes as the surrounding temperature changes. Therefore, when room temperature falls, the change in resistance causes a change in the magnitude of current flowing in the circuit. Variations in current flow, brought on by temperature changes, are used to operate a switching device. The switch contacts, in turn, operate an electric valve.

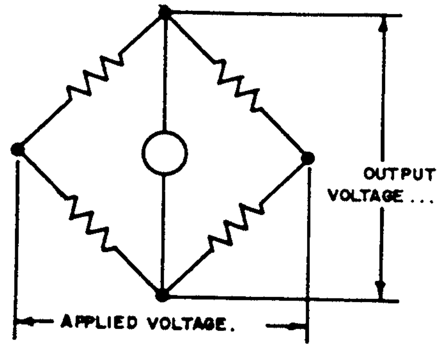
TABLE 6-3

ABBREVIATIONS

ACU	Air-Conditioning Unit
AHU	Air Handling Unit
C	Coil
C	Common
CC	Cooling Coil
CD	Cold Deck
Ch.WR	Chilled Water Return
Ch.WS	Chilled Water Supply
Com.HW	Common Hot Water
CWS	Cold Water Supply
CWV	Cold Water Valve
DA	Direct Acting
DPC	Differential Pressure Controller
DPDT	Double-Pole Double-Throw
Dpr.Act.	Damper Actuator
Dprs.	Dampers
DSPT	Differential Static Pressure Transmitter
EA	Exhaust Air
EP	Electric
GLB	Globe
h	Enthalpy
HC	Heating Coil
HD	Hot Deck
HL	High Limit
HVU	Heating and Ventilating Unit
HWR	Hot Water Return
HWS	Hot Water Supply
HWV	Hot Water Valve
M	Main
MA	Mixed Air
NC	Normally Closed
NO	Normally Open
OA	Outside Air
PE	Pneumatic
R	Relay
R	Resistor
RA	Reverse Acting
RA	Return Air
RC	Receiver-Controller
RH	Relative Humidity
RR	Reset Relay
RR	Reversing Relay
S	Sensor
SP	Set Point
SPC	Static Pressure Controller
SPRC	Static Pressure Receiver-Controller
SPST	Single-Pole Single-Throw
St.V.	Steam Valve
Sw.	Switch
T	Thermostat
T	Transformer
T	Transmitter
TR	Throttling Range
TT	Temperature Transmitter
UN	Union
UV	Unit Ventilator
VAV	Variable Air Volume



VIEW A. TYPICAL WHEATSTONE BRIDGE



VIEW B. ELECTRONIC CONTROL BRIDGE

Figure 6-16
TYPICAL WHEATSTONE BRIDGE

643.2 Wheatstone Bridge

The basic component in an electronic circuit, as applied to heating, ventilating, and air conditioning, is the Wheatstone Bridge. (See Figure 6-16.) This unit is a specific arrangement of electrical resistances connected in a network.

643.3 Direct Digital Control

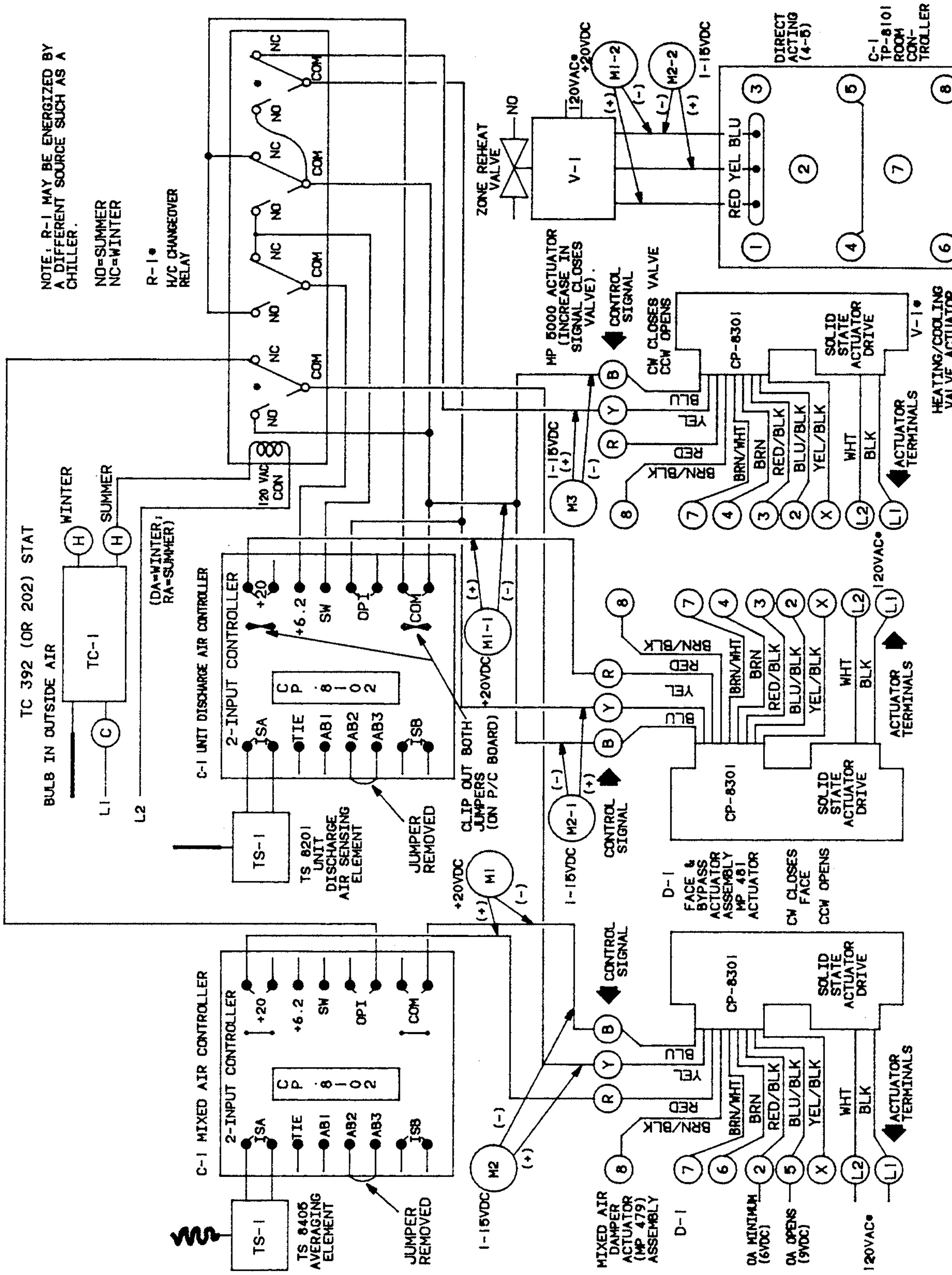
Modern technology has evolved into the direct digital control system. These systems use a microprocessor as the controller and either electric actuators or transducers to pneumatic actuators to control the medium. Resistance temperature detectors (RTD) have been developed to replace thermistors as the most accurate temperature sensors. Thin-film capacitors are the newest in technology for humidity sensors.

643.4 Digital Control Advantages

These systems, through the use of programmable interface panels, can be used for total control of large postal facilities. They offer energy management reports such as a record of peak power usage, load shedding, and scheduling and cycling of air handlers and lighting throughout the building. Use of these systems for energy conservation has proven effective.

643.5 Thermistors

Solid-state technology has changed the electronic control industry. Most electronic controls must receive a regulated DC voltage from a power supply. The exact value of this regulated voltage will change from manufacturer to manufacturer. The normal temperature transmitter is a temperature-sensitive resistor known as a thermistor. Thermistors may increase or decrease resistance on a temperature increase. The amount of resistance increase or decrease varies and the manufacturer's literature should be consulted for exact figures.



•IMPORTANT-DE-ENERGIZE (OR BYPASS) R1 TO SERVICE MIXED AIR (D1) AND VALVE (V1) CONTROL SYSTEMS.

•120VAC MUST BE ENERGIZED BEFORE ATTEMPTING SERVICE

Figure 6-17

HEATING/COOLING FACE AND BYPASS MULTIZONE WITH HOT WATER ZONE REHEAT SERVICE WIRING DIAGRAM

643.6 Electronic Controls

Most solid-state electronic control systems use electric controllers for high limits or a sliding-scale high-limit enthalpy controller. Electric relays are installed between the limit controllers and the electronic single- or dual-input controllers. The electronic controllers can be used as either direct acting or reverse acting to match the application. Electronic relays used in these systems include: reversing, signal selecting, sequencing and paralleling. Complex applications may use several electronic relays. Actuators may be electric motors equipped with actuator drives, electro-hydraulic transducers, semiconductor-controlled rectifiers (SCR) electric heat controllers, and single- or two-stage relays. The devices can control electric heat, direct-expansion refrigeration systems, rooftop air handling units, and all other types of air handlers used in postal facilities. Figure 6-17 illustrates a complex application.

643.7 Electronic-Pneumatic

.71 Description. Electronic controllers are designed for fast, accurate sensing. Pneumatic actuators, used in conjunction with positioning relays, offer the fastest movement of dampers or valves. A combination of the electronic control and pneumatic movement is used in several postal facilities. The system is a complex application that offers the best of both systems. Transducers are used to convert the electronic signal to a usable pneumatic signal. Generally, application and operation of electronic-pneumatic-control systems are described in terms of temperature control. Humidity and other variables are controlled by a similar electronic system in the same way.

.72 Wheatstone Bridge. In Figure 6-18, T_1 represents a room or zone thermostat. The sensing element of the thermostat is a coil of wire acting as resistance in the bridge circuit. If all the resistances in the bridge had the same value, there would be no current flow through the galvanometer (G), when the switch (S) was closed. If the resistor in T_1 experiences a lower temperature, AD will have a lower resistance than AC. This will make point D positive with respect to point C and current will flow from C to D through the galvanometer (G). If the resistor in T_1 experiences a higher temperature, AD will have a higher resistance than AC. This will make point C positive with respect to D, and current will flow in the opposite direction, from D to C.

.73 Two-Bridge Network. Two bridges are used to establish the relationship between T_1 (room or zone thermostat) and T_2 (duct discharge or submaster thermostat). (See Figure 6-14.) One bridge is referred to as the main bridge and the other as the auxiliary bridge. (See Figure 6-19.) The resistance wire in the T_1 thermostat forms one leg of the main bridge. Any change in the room or zone temperature causes an imbalance in the main bridge circuit. This imbalance produces a signal of a few millivolts that is impressed across the terminals of the amplifier. The resistance wire in the discharge duct or submaster thermostat is in an averaging tube that senses temperature variation across the discharge duct. The sensing element forms one leg of the auxiliary bridge. This bridge is connected in parallel with the main bridge and the two, in turn, are connected by a ratio adjustment potentiometer. The potentiometer in the circuit determines the number of degrees change T_2 must make for each degree change in T_1. It is connected with the amplifier to balance out the phase and strength of the incoming signal. The potentiometer makes the damper motor capable of proportional operation. The adjustment is determined by design and operating conditions; upon installation, any required

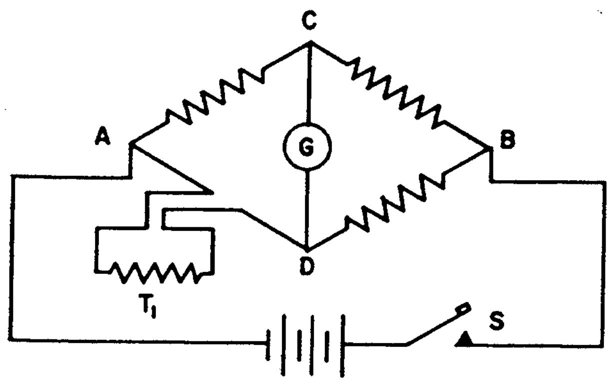


Figure 6-18
BASIC WHEATSTONE BRIDGE

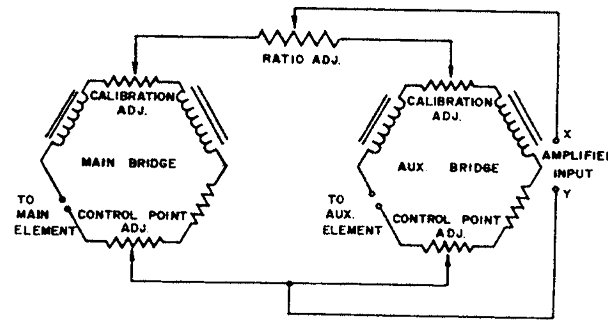


Figure 6-19
TWO-BRIDGE NETWORK

adjustment is made by the control company. When the temperature of the discharge air is such that space conditions are satisfied, the voltage between the two bridges becomes balanced. With no signal across the amplifier terminals, a null point is reached.

.74 **Single-Zone Heating-Cycle Control.** Single-zone heating-cycle operation is as follows:

a. The chilled-water pump is off. No water is flowing through the chilled-water coil. The hot-water pump is running heated water from the boiler through the hot-water coil. (See Figure 6-14.)

b. As the temperature in the room represented by T_1 decreases, there is a decrease in resistance in T_1. Thus a negative phase signal is impressed across an amplifier, and T_2 calls for sufficient heat to satisfy space requirements and rebalance the bridge system. The dampers react as follows:

(1) Decreasing voltage on the control-system solenoid coil opens the restrictor on the air bypass that, in turn, lowers the pressure on the piston and starts the face damper opening and bypass damper closing.

(2) Controlled by a reversible shaded-pole motor, the return damper D_3 moves toward the open position.

c. As the temperature in the room represented by T_1 increases, there is an increase in resistance in T_1. Thus a positive phase signal is impressed across the amplifier. T_2 calls for sufficient cooling to satisfy space requirements and rebalance the bridge system. The dampers react as follows:

(1) Increasing voltage on the solenoid coil in D_1 closes the restrictor on the air bypass that, in turn, raises the pressure on the piston and starts the face damper moving toward the closed position. As continued cooling is needed

the face damper moves to a completely closed position and the bypass damper to a fully open position.

(2) Should more cooling be needed, the outside fresh-air damper motor starts the damper moving toward the open position as soon as the face damper is fully closed. The motor is a reversible, shaded-pole type, with the shaft spring loaded to close the damper in case of power failure. This prevents freezing of the coil.

(3) In an overheated situation, the D_3 return damper moves toward its minimum open position. The return damper remains in this minimum position as long as the fresh-air intake damper is open.

.75 Cooling-Cycle Control. Cooling-cycle operation is as follows:

a. The hot-water pump is normally off No water is flowing through the hot-water coil. The chilled-water pump is running chilled water from the refrigeration plant through the chilled-water coil. As the temperature in the room represented by T_1 increases, there is an increase in resistance in T_1. Thus a positive phase signal is impressed across the amplifier. T_2 calls for sufficient cooling to satisfy space requirements and rebalance the bridge system. The dampers react as follows:

(1) Increasing voltage on the solenoid opens the restrictor on the coil bypass which, in turn, lowers the pressure on the piston and starts the face damper (D_1), moving toward the open position and the bypass damper to the closed position. In the single-zone unit, the reversing relay reverses connections to the motor's starting windings and has the same sequence of operation on the face and bypass dampers D_1 in both heating and cooling seasons. This is only true for the single-zone unit.

(2) When operating under the mechanical cooling cycle, damper D_2 is controlled by the outside limit thermostat, T_3. Since the setting of T_3 is normally 78 °F, damper D_2 will be in the minimum position (or closed position when separate minimum-position damper is provided) when the outside temperature exceeds 78 °F.

(3) Since D_3 operates inversely in relation to D_2, D_3 will be in its normal, open position.

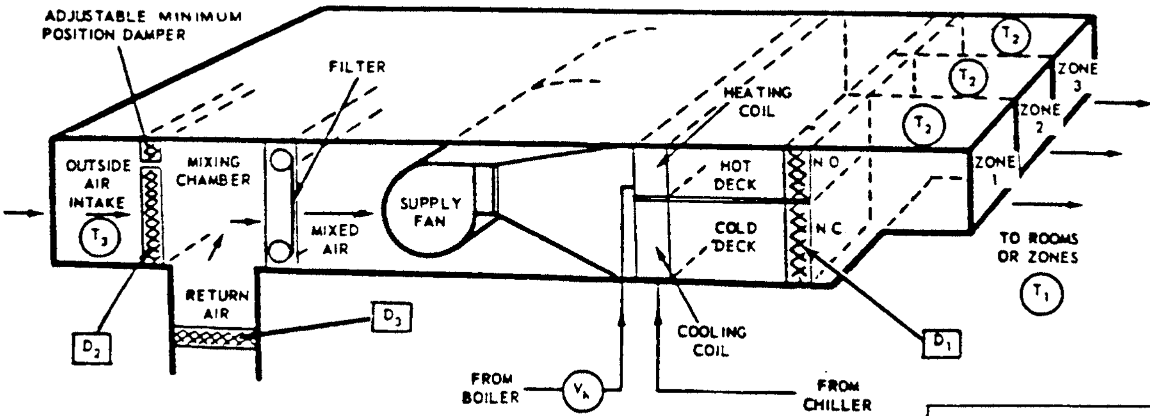
b. As the temperature in the room represented by T_1 drops, there is a decrease in resistance in T_1. Thus a negative phase signal is impressed across the amplifier. T_2 calls for sufficient heat to satisfy space requirements and rebalance the bridge system. The dampers react as follows:

(1) Decreasing voltage on the solenoid coil for D_1 starts closing the restrictor on the air bypass which, in turn, raises the pressure on the piston and starts the face damper (D_1) moving toward the closed position. As continued heating is needed, (D_1) moves the face damper to a completely closed position with the bypass damper fully open.

(2) D_2 (fresh-air intake damper) remains in minimum or closed position.

(3) D_3 (return damper) remains in open position.

.76 Outside Cooling Cycle (Economy Cycle). This cycle is used when the building can be cooled with outside air instead of using the mechanical cooling plant. This is particularly true during the late fall, early spring, and certain days and nights during the summer. Under this cycle, there will be no hot water flowing through the heating coil or chilled water flowing through the cooling coil. In the interest of economy, this cycle should be used whenever



LEGEND	
D_1	Face and Bypass Damper
D_2	Fresh Air Intake Damper
D_3	Return Air Damper
V_h	Three-Way Mixing Valve
T_1	Room Thermostat
T_2	Submaster Thermostat
T_3	Outside Limit Thermostat

Figure 6-20

TYPICAL MULTIZONE AIR HANDLER

possible. Damper control is accomplished through the T_1-T_2 relationship referred to in Section 643.73. With the refrigeration plant shut off, the fresh-air damper (D_2) is under control of the T_2 submaster thermostat in the discharge duct. Since the outside dry-bulb temperature will be less than 78 ^oF, the outside fresh-air intake damper may open when T_1, the room thermostat, calls for cooling. The action of the face and bypass dampers (D_1), the fresh-air intake damper (D_2), and the return damper (D_3) is the same as that described in Section 643.75.

.77 Multizone Cycle Control. With the exception of the face and bypass dampers (D_1) the control sequence for the multizone unit is the same as that for the single-zone described in Section 643.74. In the multizone unit, there is no reversing relay as described in Section 643.75. Dampers (D_1) perform the same for both the heating and mechanical cooling cycles. (See Figure 6-20.)

644 ELECTRIC CONTROLS

644.1 General

Electrical energy is sometimes used to transmit the controller's measurement of a change in a controlled condition to other parts of the system and to translate that measurement into the mechanical movement necessary to adjust the travel of the control element. The relatively weak impulse received from the sensing element is readily amplified

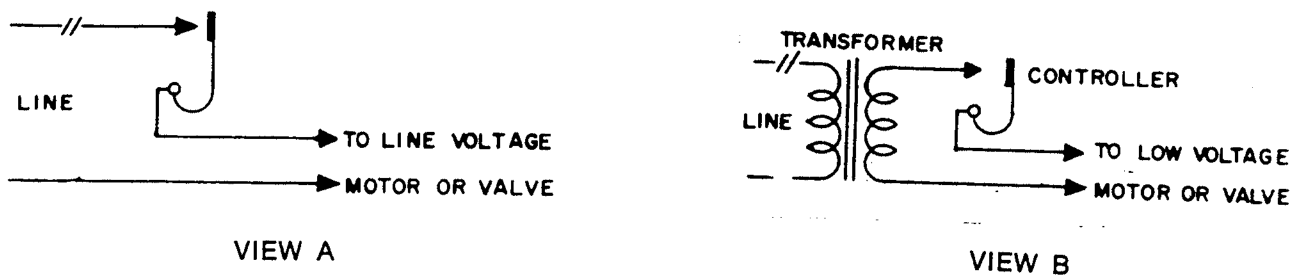


Figure 6-21
TWO-WIRE CONTROL CIRCUITS

to produce a usable voltage. The amplified electrical power may then do the mechanical work of opening or closing valves or dampers and starting and stopping machinery. Electric systems are commonly used in small buildings such as satellite facilities. Modern control techniques have produced the programmable controller. Manufacturers of such controllers have designed these devices to include features such as night setback, night setup, weekend setback, and weekend setup. These features can be used to conserve energy.

644.2 Operating Principles

In automatic electric control, two voltages are used. The term low voltage applies to wiring and electrical devices using 25 volts or less. In most low-voltage applications, the device is normally a control unit or actuator using relatively little power. It may be a relay, a solenoid or motorized-type valve, or a damper motor. The other voltage is line voltage, generally either 115 or 230 volts. A line-voltage controller directly operates a major piece of equipment such as a fan motor, a line-voltage valve, or a control motor. It is also connected to the primary side of a step-down transformer to provide power for a low-voltage circuit. Besides starting and stopping current flow, electric control circuits require that the magnitude of the current be regulated. This function is carried out by means of a variable resistor called a potentiometer.

644.3 Relays

To do mechanical work, an electric-control system must include some means of transforming electrical energy into mechanical energy. For actual control work, the usual method is through a magnetic coil or solenoid. The solenoid is used for operating a valve or a coil-and-armature mechanism with contacts (relay) to control airflow.

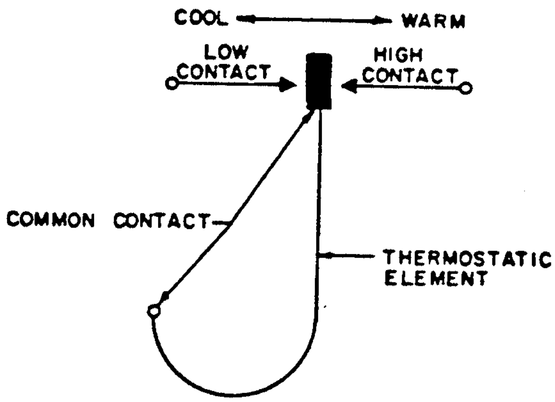


Figure 6-22
DOUBLE-THROW THREE-WIRE CONTROLLER

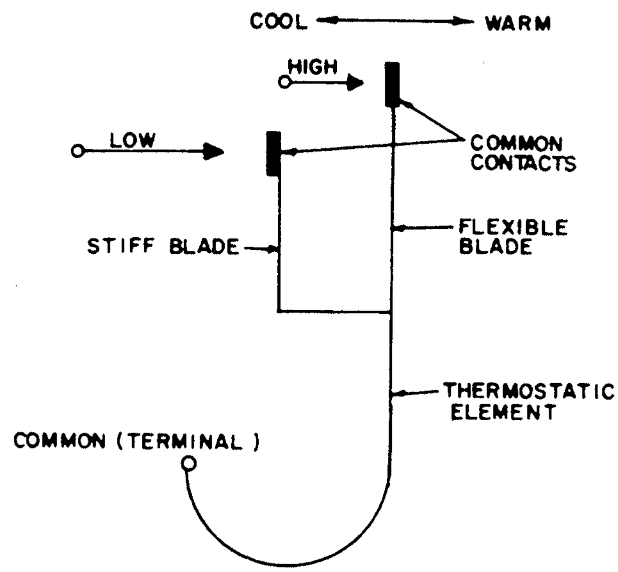


Figure 6-23
SINGLE-THROW THREE-WIRE CONTROLLER, SEQUENCE CONTACTS

644.4 Electric Control Circuits

.41 Classification. Like electronic circuits, electric control circuits are classified as two-position (full-on or full-off), floating, or proportional. Two-position circuits are further classified into two- and three-wire circuits, using line and low voltage. Figure 6-21A and Figure 6-21B show line-voltage and low-voltage, two-wire circuits. In each case, the contacts are essentially a switch that turns the electric power on or off to operate some device. In low-voltage applications, the operated device may be a relay, a solenoid, a motorized valve, or a damper motor. The contacts in these circuits return to their normal deenergized position without electrical assistance. Some use spring action to return to their normal position, while others use the weight of the coil core. Three-wire, two-position, control units consist of either single-pole, double-throw (Figure 6-22), or sequence single-throw contacts (Figure 6-23). The three-wire, two-position control has a common contact and a high and low contact. These terms, in the case of a heating-control thermostat, refer to the temperatures at which the contacts close. The sequence single-throw unit also has a common contact on a flexible blade that bends with temperature change and allows the high contact to be made first. Additional movement engages the low contact. The contacts close in

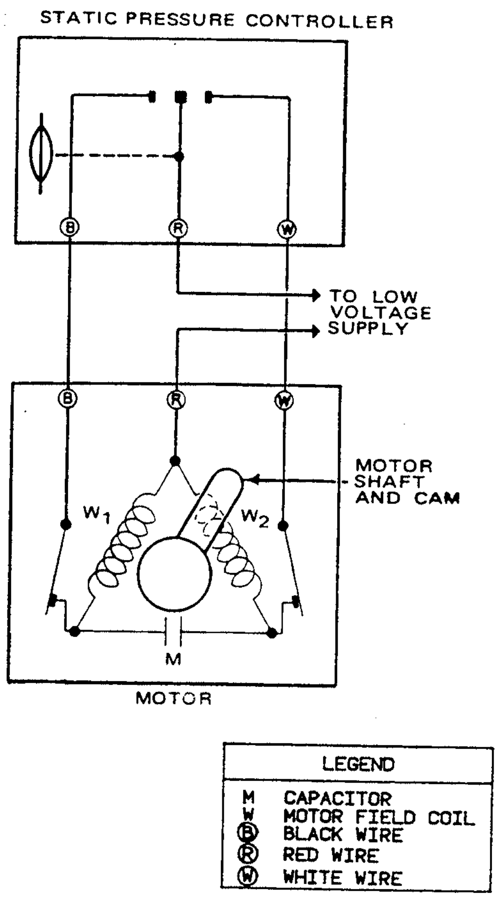


Figure 6-24

FLOATING-CONTROL CIRCUIT

sequence as the controlled condition reaches two predetermined points. The first contact closes the starting circuit and the second contact closes a holding circuit to prevent chattering action of the control. The contacts disengage in reverse sequence when environmental conditions are satisfied.

.42 Floating Control. The floating-control circuit has no fixed number of positions, but allows the controlled element to assume any position from one extreme of motion to the other. This is possible as long as the room temperature or other controlled variable condition stays within the limits of the controller. Figure 6-24 shows a typical floating circuit using a low-voltage supply and a double-throw, three-wire controller. Line voltage can also be supplied to a floating control. When the common contact engages the high contact, power is supplied to motor field coil W and to coil W_2 through capacitor M. The motor then rotates in the proper direction to make the necessary corrections. When conditions change in the opposite direction, the common contact engages the low contact. The connections to W_1 and W_2 are reversed, and the motor rotates in the opposite direction until the circuit is broken again. When the common contact does not contact either the low or high contact, conditions are satisfied and the motor remains stationary. Proportional-control circuits are so designated because they provide variable control (temperature, humidity, or pressure) proportional to changes in demand. They operate to position the controlled device at any point between fully open and fully closed, and then proportion the delivery to the need as dictated by the controlled device. Proportional-control circuits may be applied to motorized valves, motorized dampers, and sequence-switching mechanisms.

.43 Controller Components. Controllers for proportioning circuits have a variable potentiometer on which the contact finger is actuated by a mechanism sensitive to temperature, pressure, or humidity. Other components making up the control are a reversible-power unit, a balancing relay, and a balancing potentiometer. (See Figure 6-25.) The power unit is a reversible, capacitor-type motor connected to either line- or low-voltage circuits. The motor drives the output shaft through a gear train. Limit switches are operated by the shaft to limit its rotation to 90 or 160 degrees. The power unit is started, stopped, and

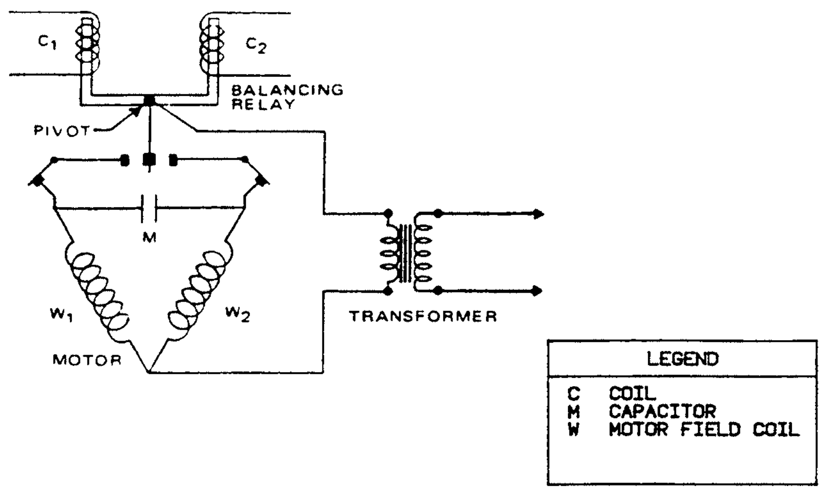


Figure 6-25

DIAGRAM OF BALANCING RELAY AND MOTOR CIRCUIT

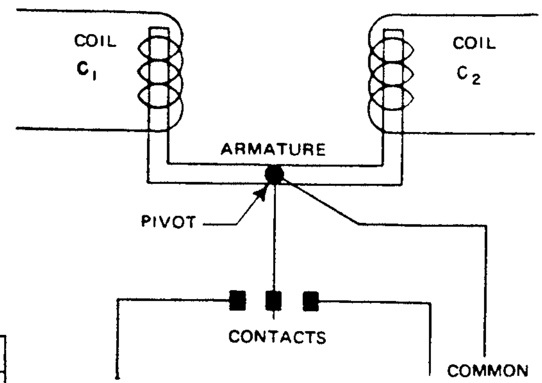


Figure 6-26

DIAGRAM OF BALANCING RELAY

reversed by the single-pole, double-throw contacts of a balancing relay. (See Figure 6-26.) The balancing relay consists of an armature pivoted on one end and swinging between two electromagnetic coils. As the magnetism of the two coils changes due to changes in current flow, the armature moves toward the stronger coil. The swinging armature usually has a two-contact arm set to contact two stationary contacts to complete the circuits involved at certain armature positions. This relay, usually mounted in the motor, is a low-voltage installation. The function of the balancing relay is illustrated in Figure 6-25. A balancing potentiometer is also built into the motor housing. This potentiometer is identical to the controller potentiometer, except that the contact finger is operated from the motor shaft.

.44 Current Flow. Figure 6-27 shows a typical circuit. When the current reaches the potentiometer winding of the controller, the current is evenly divided with half of it flowing down the right leg and the other half down the left leg. The current flows through the controller potentiometer, the balancing relay coil, the balancing potentiometer coil, and then back to the transformer. The resistances of coils C_1 and C_2 are identical; therefore, the amount of current flowing in the two legs depends upon the total potentiometer resistance in each leg at any given time. Figure 6-27 shows a static and balanced condition of the system.

.45 Motor Operation. Equal amounts of current are flowing in each leg. Any change in temperature detected by the controller will change the position of the wiper finger on the controller potentiometer. This makes the amount of resistance to either side of the wiper unequal. The resistance path on one side of the circuit is considerably less than the other. It follows, then, that more current flows down one side than the other. Since there is more current flowing through one relay coil, this coil overbalances the other and a circuit is completed through the armature contact and the balance relay contact on the same side. Current now feeds directly to

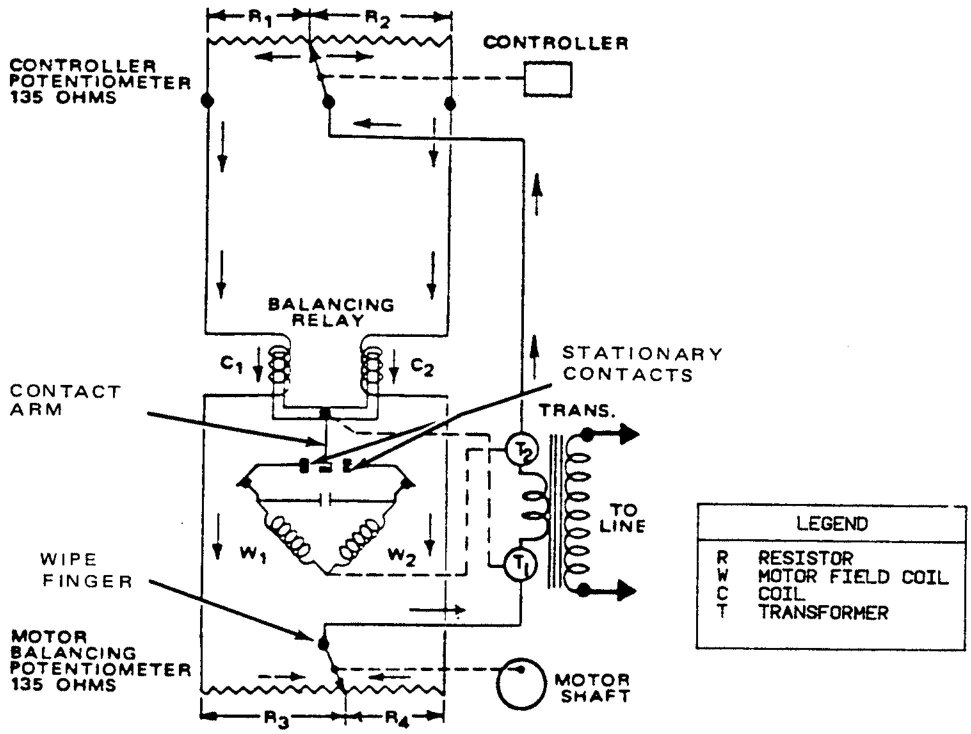


Figure 6-27

TYPICAL BALANCING RELAY CIRCUIT WITH PROPORTIONAL MOTOR

one set of motor windings and causes the motor to run in the appropriate direction. The wiper finger of the motor-balancing potentiometer is linked directly to the shaft of the motor. As the motor shaft starts to turn, the wiper finger of the balancing potentiometer moves to a new position corresponding to the position of the controller potentiometer wiper in the thermostat. This means that the resistances on both sides of the balancing relay are equal again. The balancing relay coils have an equal effect on the armature; the contact arm settles at a point between the stationary contacts and the motor stops. By studying Figure 6-27, it can be seen that the motor will run whenever the resistance on either side of the potentiometer wiper of the controller is moved as a result of a change in temperature that unbalances the resistance circuit. The motor will continue to run until the resistance of the balancing potentiometer is the same as that of the control potentiometer. At this point, the balancing relay coils again balance out and the motor comes to a stop. The entire system will remain in this position until temperature changes dictate moving the system to another position.

NOTE

The above descriptions of electric control circuits are used in a general way. There are variations to these descriptions, but the fundamentals are the same.

645 PNEUMATIC CONTROLS

NOTE

The pressures used in the examples in this section are examples only. Different manufacturers use various pressures in their controls. That information should be checked prior to adjusting the controls.

645.1 Basics

Pneumatic controls are commonly used for controlling heating and air-conditioning equipment in Postal Service applications. They use compressed air to supply energy for the operation of valves, relays, operators, and other pneumatic-control equipment. Generally these systems detect a change in environmental conditions (temperature, relative humidity, or pressure) and act to position a controlled device to maintain the environmental conditions at the desired level. The air used to power these controls is supplied by an electrically driven air compressor. Air is supplied to the control system at 20-25 psig. Certain control systems employ dual-element (day/night or summer/winter) thermostats, and the air supply to those devices is switched from 13-15 psig to 20-25 psig depending on the operation desired. Air lines that lead from the air supply to the controlling devices are labeled as main or supply air. Air lines that lead from the controlling device to the controlled device are designated branch or output.

645.2 Typical Pneumatic Control System Components

.21 Figure 6-28 shows a typical pneumatic-control system. The air compressor should produce control quality air and be dedicated only to the pneumatic-control system. It must supply air that is clean, dry, and free of oil. The compressor must be maintained according to manufacturer's recommendations. Particular attention must be paid to cleaning the air intake filters and keeping the receiver tank free of excess moisture. Cross-connection with the plant or process air system or the use of a screw-type compressor is not recommended due to the possibility of oil contamination. Air receivers are classed as pressure vessels and must be inspected and maintained in accordance with current postal regulations. Standard filters in the air lines remove particulate matter, coalescing filters remove aerosol oil particles, and refrigerated air dryers remove moisture by cooling the supply air below its dew point and draining off the resulting condensate. Most control manufacturers recommend that the supply air contain less than 1 part per million oil. Excessive oil can block the internal passages and orifices of the pneumatic controls and rot away their rubber parts. Control compressors should run approximately one-third to one-half of the time to allow adequate cooling time between operating cycles. Excessive compressor running time may be caused by numerous leaks in the control system, an undersized compressor, or a worn or defective machine. The air receiver is usually operated at 80 to 120 psig and a reducing valve lowers the pressure to 20 to 25 psig to supply the controls.

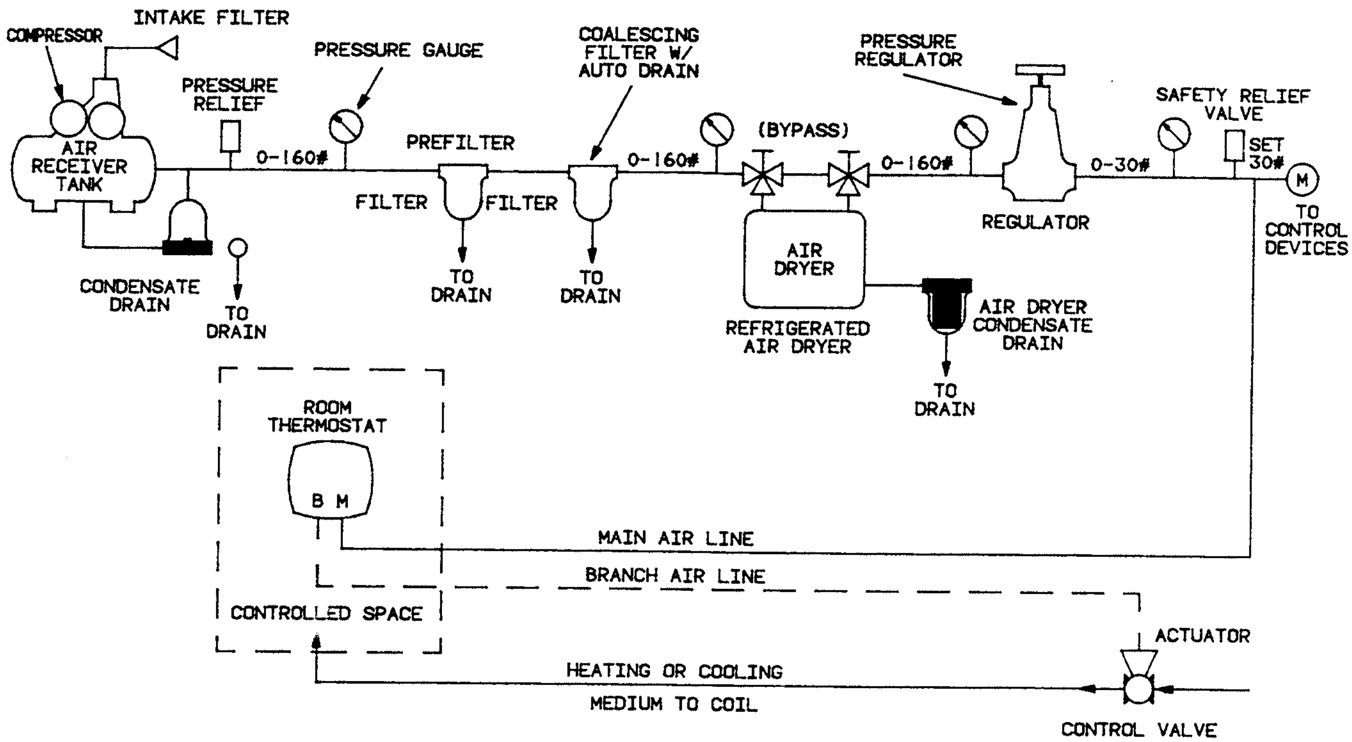


Figure 6-28

TYPICAL PNEUMATIC SYSTEM

.22 The controlling device may be classified as a thermostat or a receiver-controller. The thermostat has some type of temperature-sensing element, generally a bimetal or refrigerant-filled bulb, attached to the device while a receiver-controller utilizes a remote sensing element that transmits a pressure proportional to the quantity being sensed. Both the thermostat and the receiver-controller meter out air pressure to the controlled device in response to a change in the measured condition. If the change in branch or output pressure is gradual, the device may be said to operate proportionally. If the branch line changes rapidly from zero to maximum with no intermediate operation, a two-position or positive operation is provided. Pneumatic-control systems utilize proportional control in all but a few applications.

645.3 Thermostats

.31 **Single-Element Room Thermostat.** Figure 6-29 shows a typical, single-element, room thermostat. The room thermostat may be used to position a water valve supplying a fan coil unit, a heating zone valve, a zone or discharge air damper, or face and bypass dampers. All modern room thermostats utilize a bimetal-sensing element and most are high-volume relay type. Relay-type thermostats are accurate, fast-acting devices and will give years of satisfactory service, if properly maintained. Regardless of manufacturer, all pneumatic-room thermostats have several test and adjustment points. The SET POINT dial is used to adjust the thermostat, to maintain a desired temperature. The OUTPUT ADJUSTMENT is used to set the output pressure of the thermostat and the SENSITIVITY or THROTTLING RANGE adjustment is used to select the number of degrees above and below the set point through which the controlled device will operate.

.32 **Temperature Range.** Most control manufacturers suggest that a room thermostat should operate the controlled device over a fairly narrow range of temperature. If the thermostat is set to move its valve or actuator over a small change of temperature (for example, one degree), the controlled device will cycle rapidly between open and closed, and wild temperature fluctuations will occur in the space. If the throttling range is set to operate over a very wide range of temperature, the system will not be able to respond

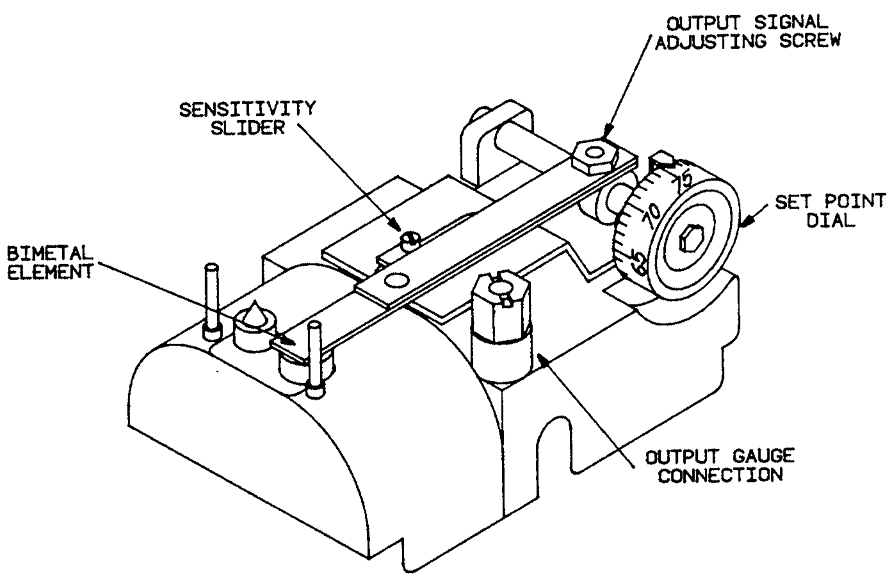


Figure 6-29
SINGLE-ELEMENT ROOM THERMOSTAT

fast enough to changes in load. Experience has shown that throttling ranges of three to four degrees are satisfactory in room temperature control applications. If a room thermostat is controlling a fan coil valve that operates over an 8-13 psig pressure range and the desired throttling range is four degrees with a 65 °F winter set point, the valve should be fully open (8 psig) at 63 °F and fully closed at 67 °F (13 psig). The throttling range or sensitivity adjustment should be set to produce the required five pound change in pressure over the four degree change of temperature.

.33 **Room Temperature.** If the room temperature is found to be outside of the desired throttling range and if conditions warrant (for example, room temperature above 65 °F with heat still being added during winter operations), it may be necessary to calibrate the thermostat. While manufacturer's literature and operating instructions should be consulted for specific information, the general steps of calibration may be outlined as follows:

a. Take the ambient temperature in the space using an accurate dial, bulb, or electronic thermometer. Thermometers provided in the thermostat covers are not accurate enough for this purpose.

b. Adjust set point dial to the ambient temperature.

c. Adjust output pressure of the thermostat to the middle of the controlled device's operating range (midspring).

d. Adjust set point dial to desired temperature.

.34 **Output Pressure.** Single-element thermostats may be either direct or reverse-acting. Direct-acting thermostats (commonly abbreviated D.A. or DIR) increase their output pressure as the temperature being sensed increases. Reverse-acting (R.A. or REV) devices decrease the output pressure as the temperature increases.

.35 **Dual-Element Thermostats.** Summer/winter thermostats utilize a direct-acting and reverse-acting element and are used to control face and bypass air handlers or single pipe, fan-coil units which utilize the same, normally open valve for heating and cooling. Since face and bypass dampers are normally open to the face of the coils, winter operation requires the thermostat to close the face dampers and shut off the heat on a temperature rise in the space (direct action). The same thermostat must be reverse-acting in the summer to open the face dampers and admit cool air to the space on a temperature rise. The thermostat is internally switched from a direct- to reverse-acting, temperature-sensing element by switching the supply pressure of the thermostat from (typically) 13-15 psig for direct action to 20-25 psig for reverse action. Other features of dual-element thermostats are as follows:

a. Day/night thermostats also utilize two sensing elements. These thermostats are used for automatic lowering of heating set points during unoccupied hours. The day element is set for the "occupied" set point of 65 °F degrees. The night element has a set point which is usually ten degrees below the day set point and maintains the space at a minimal level of heating during unoccupied hours. Day/night thermostat set points are switched by changing the supply pressure of the thermostat.

b. Supply lines to dual-element thermostats must be separated from the rest of the control system supply mains. Other pneumatic-control devices such as receiver-controllers, temperature transmitters, and relays must operate on a constant 20-25 psig supply. They become

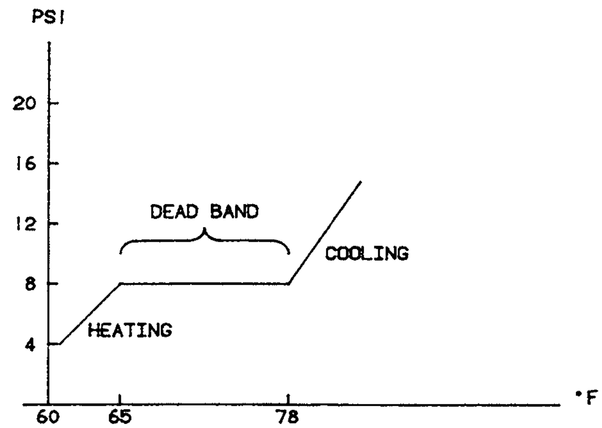


Figure 6-30
DEAD-BAND THERMOSTAT OUTPUT PRESSURE VERSUS TEMPERATURE

inaccurate or inoperative if the supply pressure drops to 15 psig.

.36 **Dead-Band Thermostats.** Air handlers using the sequenced valves and dampers method of operation can be controlled by dead-band thermostats. These thermostats are designed to operate all year without seasonal changes of set point as they control the building's heating system when the space temperature is below 65 °F and operate the cooling apparatus when the space temperature exceeds 78 °F. Between 65 °F and 78 °F a dead- or free- energy band exists where the building is operating without the use of any heating or cooling energy. Some dead-band thermostats have an adjustable, freeenergy band while others are fixed at 13 °F. (See Figure 6-30.)

.37 **Remote-Element and Insertion Thermostats.** Older or less complex systems often utilize remote-element or insertion thermostats. (See Figure 6-31.) These thermostats are mounted at or near the location where temperature is sensed and detect temperature changes through the use of a refrigerant-filled bulb and capillary tube or a rod-and-tube-type, insertion element. These devices are reliable and easy to calibrate, but lack temperature indication

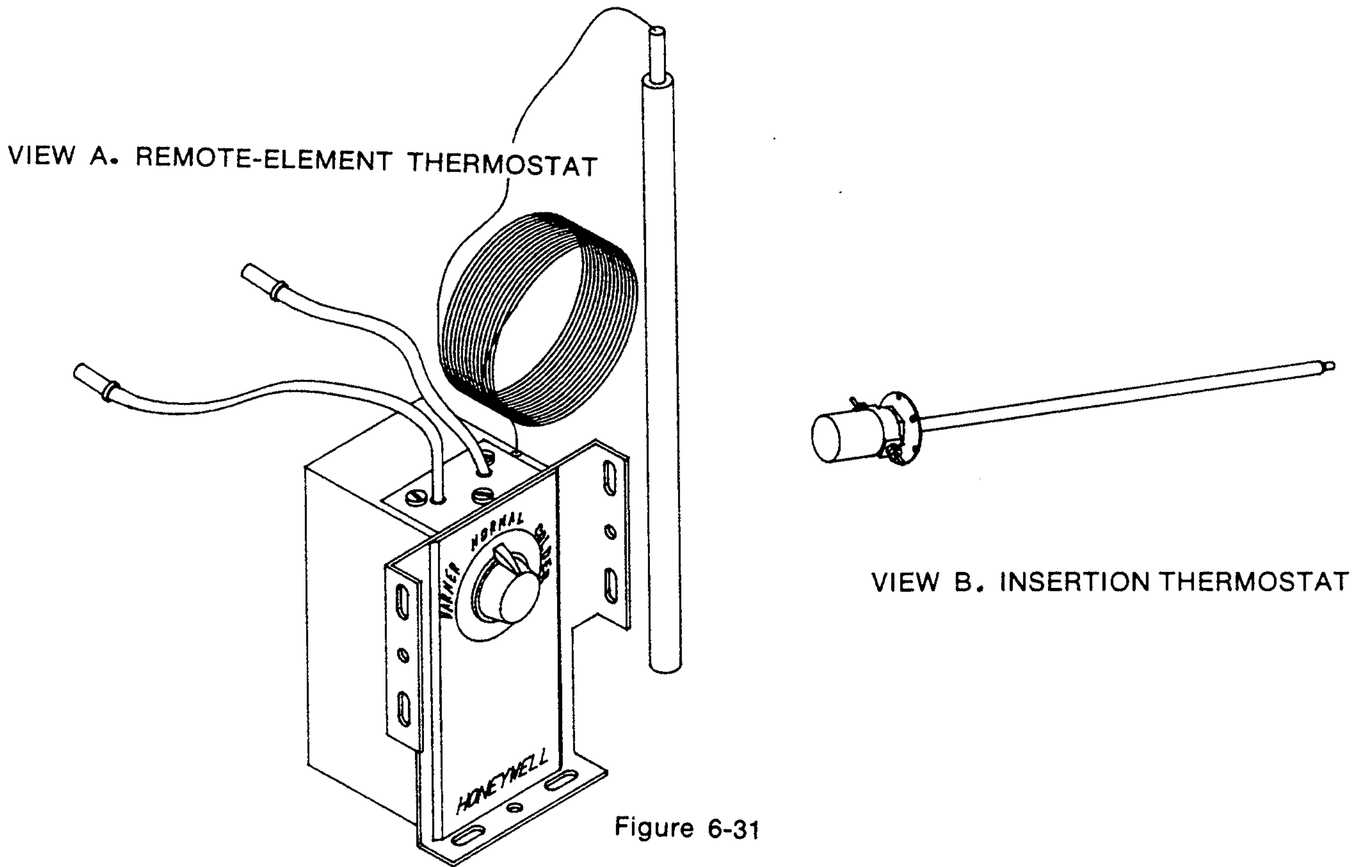


Figure 6-31

THERMOSTATS

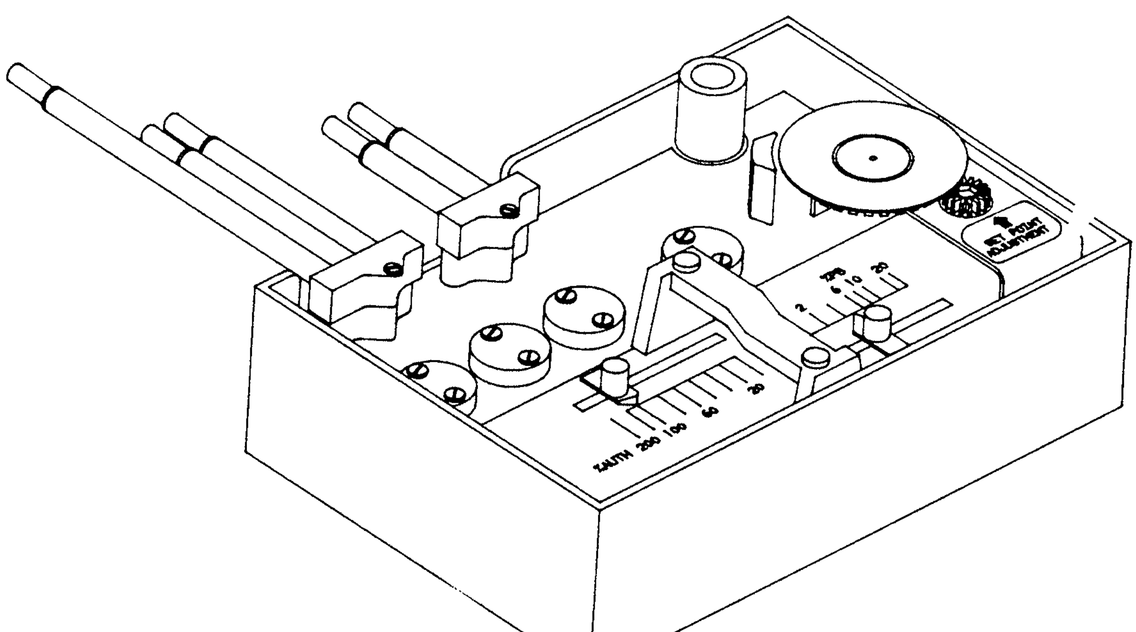


Figure 6-32

RECEIVER-CONTROLLER

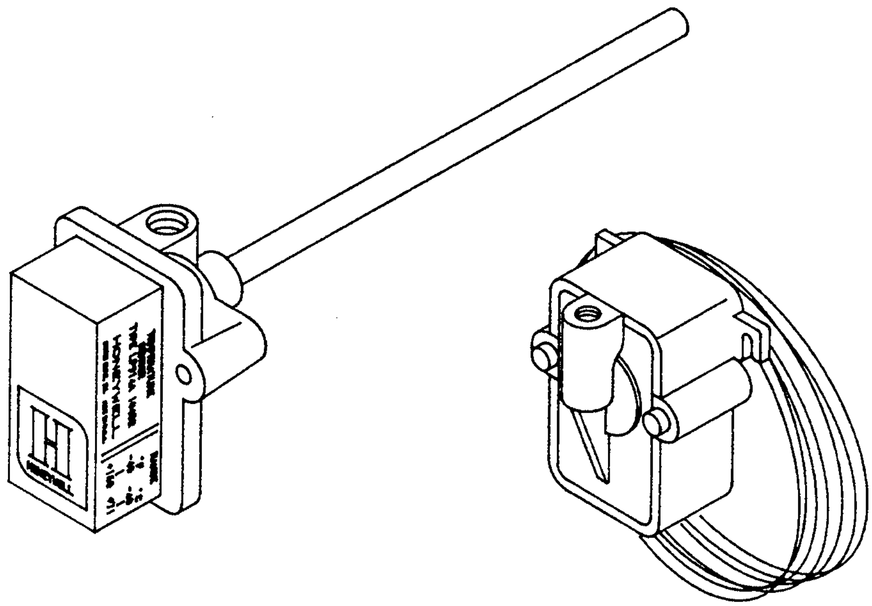


Figure 6-33
TEMPERATURE TRANSMITTERS

and remote set point capability. Typical applications would include high limits (economizers) or steam valve control on steam to hot water converters.

645.4 Receiver-Controllers

.41 Modern pneumatic-control systems use various combinations of remote, temperature-sensing elements and receiver-controllers to operate valves and dampers in the control system. The controller/transmitter system allows for remote temperature indication through the use of analog gauges, central location of all controls in a cabinet or on a panel, and for the use of remote set point adjustment from a building monitoring computer. (See Figur 6-32.)

.42 Temperature transmitters or remote sensing elements (Figure 6-33) are used for temperature detection in receiver-controller systems. These remote sensors operate over fixed temperature spans which are marked on the device and over a 3 to 15 psig pressure span regardless of manufacturer. Remote sensors may be easily checked for accuracy by comparing a known temperature to the output pressure of the transmitter. These devices are constant-bleed-type instruments and require air supplied through an orifice or restriction of a definite size. The restrictor may be located inside the receiver-controller or it may be mounted in the air line connecting the transmitter and controller.

.43 Analog gauges are often found in the sensor lines. These gauges provide direct temperature indication by converting the 3 to 15 psig sensor pressure to the proper temperature. If these gauges are used, the gauge scale must match the range of the temperature transmitter being used. For example, a 0 to 100 °F range analog gauge must be used with a 0 to 100 °F temperature transmitter.

.44 Single-input receiver-controllers utilize one remote temperature transmitter and operate the controlled device to maintain a particular desired temperature. The single-input controller has two adjustments: percent proportional band or percent throttling range and set point. The percent throttling range expresses the desired throttling range of the controller as a percent of the sensor span. Set point is used to select the desired operating temperature of the system. Control manufacturer's literature should be consulted for specific instructions on calibrating the set point and throttling range of a single-input controller.

.45 Dual-input or master/submaster controllers use two temperature inputs. They are found in systems where it is necessary to vary the set point of one temperature in response to a change in another temperature. For example, a building hot water radiation system may be controlled by a dual-input controller. As the outside air temperature drops, hotter water should be supplied to the radiation system to compensate for increased heat losses through the building envelope. Master/submaster systems are also used to control the temperature of the air supplied to a space in response to changes in outside air temperature or the room temperature itself.

.46 A predetermined range of temperature operations, known as an operating schedule, must be decided upon and set into the controller. Schedules may be found on building control prints or may be developed by the building operators. Schedules developed prior to 1978 may maintain temperatures above or below current temperature guidelines and should be checked to maximize energy conservation.

.47 The relationship between the master (outside air) and control or submaster (hot water) temperature is expressed as ratio or percent authority. The desired operating schedule causes sensor line pressure changes that must be considered when calculating ratio or percent authority; manufacturer's literature should be consulted for the proper method of calculation. Dual-input controllers also have a throttling range setting that refers to the change in the controller's output in response to a change at the control sensor, and a set point adjustment. To find the desired set point of a master/submaster controller, the master temperature is first checked and the control set point is found by the use of a set point graph. See Figure 6-34 for a typical schedule and set point graph.

.48 Certain systems, particularly those originally fitted with a building monitoring computer, have a capability for remote set point adjustment. These systems use an extra port on the single- or dual-input receiver-controller and a pressure change to that port shifts the set point of the controller over a predetermined range. Remote set point adjustment may be made through the use of an electropneumatic transducer or a gradual switch.

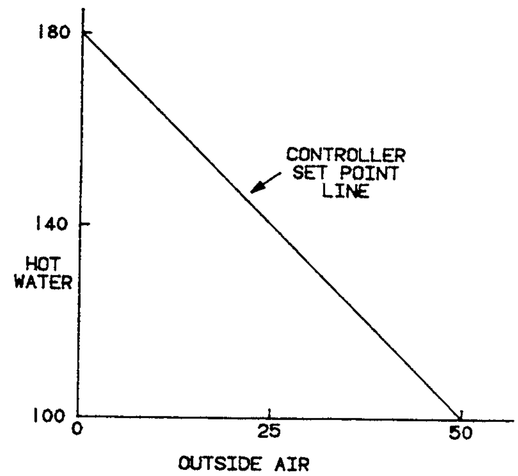
645.5 Relays and Auxiliary Devices

.51 Relays and auxiliary devices generally may be considered to be any device that changes the output signal of a controller. Some typical relay types and applications are listed below:

a. Reversing relay. Used to reverse the output signal of a controller. Often found in face and bypass damper systems to convert the direct-acting (winter), output signal of a controller to a reverse-acting signal for summer operation.

OUTSIDE AIR	HOT WATER
0	180
50	100

VIEW A. SCHEDULE



VIEW B. SET POINT GRAPH

Figure 6-34

TYPICAL SCHEDULE AND CONTROLLER SET POINT GRAPH

b. Minimum position relay. Maintains a minimum air pressure to outside air dampers. This allows outside dampers to remain open to meet ventilation requirements while the air handler is running.

c. High or low pressure selecting relay. Often found in multizone systems. This relay allows the warmest zone to operate the cooling valves and dampers and the coldest zone to operate the heating devices.

d. Electric/pneumatic (E-P) relay. Serves as an interface between the electric and pneumatic portions of the control system. Often used as a switch or as a bleed-off device for fail-safe operation or system interlock.

.52 Volume-booster relays are used to compensate for pressure losses or time delays in long runs of control tubing. These relays are also used to amplify the output of low-volume, nonrelay-type controllers.

646 CONTROL MAINTENANCE

646.1 Scheduling

Inadequate HVAC control maintenance and calibration adversely affects energy-use reduction efforts. Recent studies of pneumatic- and electronic-HVAC controls by the Construction Engineering Research Laboratory (CERL) and the National Bureau of Standards (NBS) show that controls must be tested and calibrated on a regular schedule. The CERL study reported that controls may drift out of calibration significantly over very short periods of time. The NBS reported that a 1 °F error in the mixed-air controller of an air handler may increase energy usage as much as 11 percent above normal. Calibration errors, in addition to increasing energy usage, may cause damage by short cycling the equipment or by not responding to damaging conditions. As a general rule, pneumatic controls will require more frequent calibration than electronic controls. Controls that are exposed to adverse environmental conditions, e.g., heat, cold, vibration, and dust, will require more frequent service than controls not subjected to these conditions.

NOTE

All maintenance managers should review their HVAC control maintenance to ensure that it is adequate.

646.2 Calibration Tests

Controls that are maintained in-house should be tested for proper calibration on an annual basis as required by HBK MS-1, Operation and Maintenance of Real Property, Appendix 13-B, Guide No. A-10. Where HVAC controls are not maintained in-house, control maintenance should be contracted out to qualified professional service companies. For specifications for this service, see Chapter 7, Specification 7-4.

646.3 Inspection

When inspecting controls, look for missing parts, damaged sensors, loose wires, or air leaks. Damper actuators and associated hardware should be checked for bent or loose connecting rods. To prevent dirt contamination, covers should be removed only when servicing the control. Sensor elements should be cleaned periodically so that the dirt and oils do not form an insulating layer.

646.4 Cleaning

Pneumatic control air compressors require periodic bleeding of the accumulated water and cleaning of the filter to ensure proper operation. A coalescing-type filter should be installed between the compressor and the pneumatic system to remove oil from the air. Refrigerated air dryers or desiccant-drying systems may be used if water in the lines is a problem.

647 APPLICATIONS

647.1 Single-Zone

.11 **Single-Zone System.** This system (Figure 6-35) provides simple control of space temperature. The temperature is controlled by the direct-acting room thermostat that controls a hot water supply valve and a chilled water supply valve in response to changes in room temperature.

In operation, the branch line from the thermostat provides a 3-15 psig signal to the hot and chilled water valves. When the thermostat requires an increase in room temperature, the hot water valve opens. As the temperature increases, the branch pressure increases. When the temperature rises to the set point, the branch pressure increases to close the hot water valve.

Should the space temperature continue to rise, the direct-acting thermostat will continue to increase the branch line pressure. If the temperature rises above the set point, the normally closed, chilled water valve will begin to open. The chilled water valve has a spring range of 8-13 psig, thus it will throttle to the fully open position as temperature continues to increase.

Both valves will be closed between 6 and 8 psig branch pressure. This dead band between the two spring ranges ensures

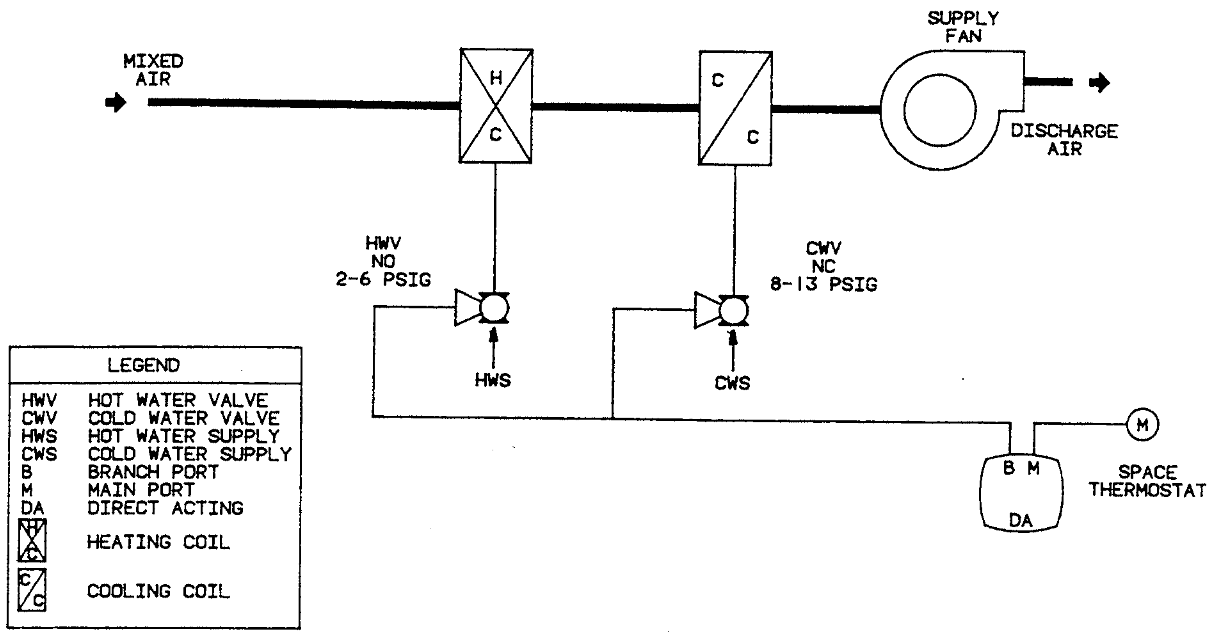


Figure 6-35

SINGLE-ZONE SPACE CONTROL

that the heating valve is fully closed before the cooling valve opens and vice versa.

.12 Single-Zone System with Low-Limit, Freezestat, and Outside Air Control. In this system (Figure 6-36) the same function is being performed by the space thermostat as in the previously discussed single-zone system. However, additional controls that are often found in conjunction with the thermostat and coil controls in a system like this are added. This system also includes control of the outside air damper, the EP relay that ties into the fan starter circuit to provide shutdown at night, and low-limit and freeze protection controls.

In this sequence of operation, the fan starter is tied to the EP relay controlling the branch line airflow to the outside air damper actuator. When the fan is off, the EP relay exhausts the branch line to the outside air damper, allowing it to fully close. Also tied into the control circuit for the fan starter is a freezestat, which is another electrical device. The other pneumatic device shown is the low-limit control. This is a bleed-type device and is located directly downstream from the heating coil and becomes active only when the mixed air temperature leaving the heating coil drops below a nominal 50-55 degrees. The additional restrictor shown is an adjustable restrictor in the line ahead of the low-limit control and the hot water supply valve. This restrictor limits the amount of airflow to the devices downstream and, in the event that the low-limit control senses a decreased mixed air temperature, the low-limit will bleed off branch line air, allowing the hot water supply valve

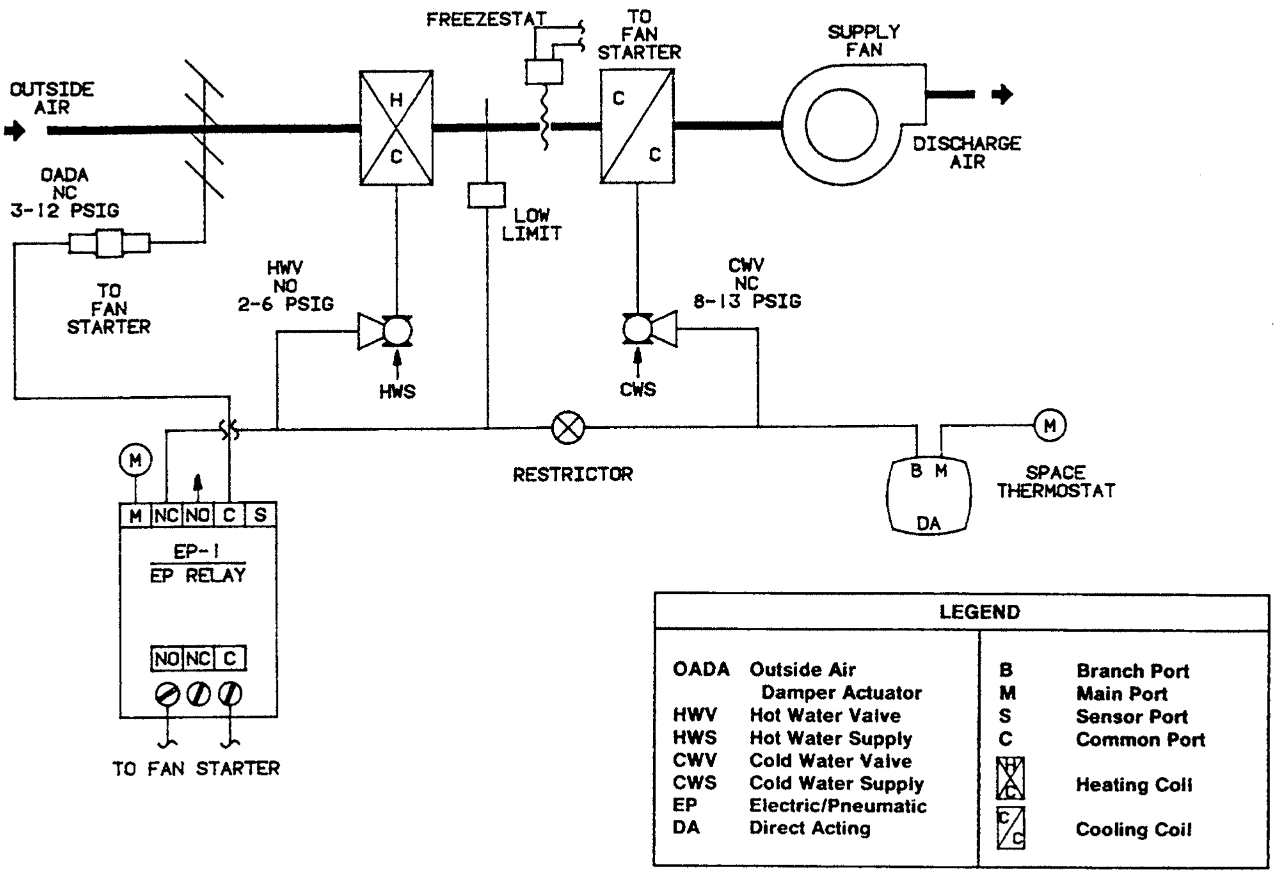


Figure 6-36

SINGLE-ZONE SPACE CONTROL WITH LOW-LIMIT AND OUTSIDE AIR CONTROL

to open further than the space thermostat may be allowing.

The freezestat previously mentioned would come into action if the low-limit control was not able to compensate for the drop in temperature by providing sufficient flow through the heating coil to enable the coil to recover. If the mixed air temperature leaving the heating coil continues to drop, the freezestat would break the control circuit to the fan starter, shutting off the fan to prevent the possibility of coil freezeup. This is a safety control that generally has a manual reset. The temperature range of this device is from 35 to 45 ^{o}F. The device must be reset manually if it breaks the fan control circuit.

Other controls may be used in conjunction with this type of system, but this provides the basics. There potentially could be a minimum-position control on the outside air damper and control of return air and exhaust air dampers.

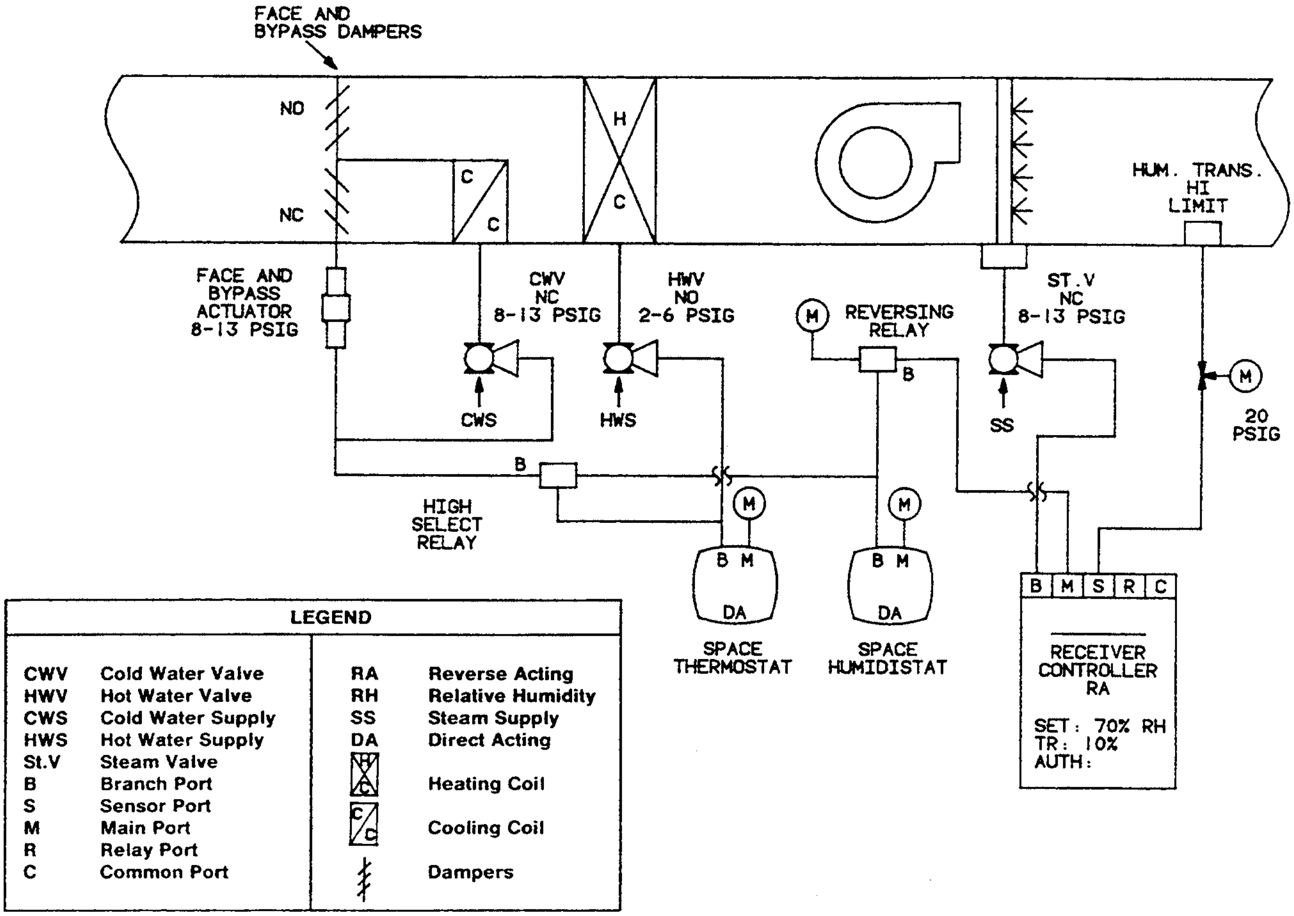


Figure 6-37

SINGLE-ZONE SPACE TEMPERATURE AND HUMIDITY CONTROL

.13 **Single-Zone Control of Space Temperature and Humidity.** This system (Figure 6-37) is similar to the previous single-zone systems which have been discussed, but has some additional control functions. This system provides humidity control in addition to the temperature control of the previous system. To facilitate humidity control, face and bypass dampers control flow through the cooling coil, and the heating coil provides reheat capability.

Basic temperature control in this system is done by the direct-acting, space thermostat which controls the hot water supply valve, the chilled water supply valve, and the face/bypass actuator sequence. Control of the hot water supply valve is direct-acting. As temperature rises in the space, branch line pressure from the thermostat increases, closing off the hot water supply valve. As pressure continues to increase in response to rising space temperature, a signal passes through the high select relay and starts to drive open the chilled water supply valve. It then closes off the bypass damper and opens the normally closed face damper.

At the same time, the space humidistat, which is also direct-acting, is sensing the humidity level in the space. Its branch line feeds the S2 port of the high select relay. If the humidity in the space rises above set point and the branch line pressure of the humidistat exceeds that of the branch line pressure of the thermostat, the humidistat branch line pressure will actuate the face and bypass damper and the chilled water supply valve to provide cooling to dehumidify the space.

At the same time, the branch line of the humidistat goes to the reversing relay which, in turn, is fed to the main air port of the reverse-acting receiver-controller. The humidity transmitter located in the duct and the receiver-controller, serve as a high limit. Should the humidifier output increase above 70 percent it will close the steam valve by reducing the branch line pressure to the normally closed steam valve.

This type of system would be used in an area where low humidity in the winter could present a problem, as well as a need for dehumidification during mild weather if the humidity were too high. As mentioned, it would be possible to open the cooling coil valve and face damper thereby cooling the air because of a high humidity condition (even though the wall thermostat might be calling for some heat). In this case, the air would be reheated by the heating coil and supplied at a temperature necessary to satisfy the demands of the space.

647.2 Mixed Air Control

.21 Mixed Air Control, Economizer The purpose of this application is to provide the maximum amount of free cooling available from the outside air. Commercial systems generally are cooling oriented because of load conditions in the controlled space. As such it is

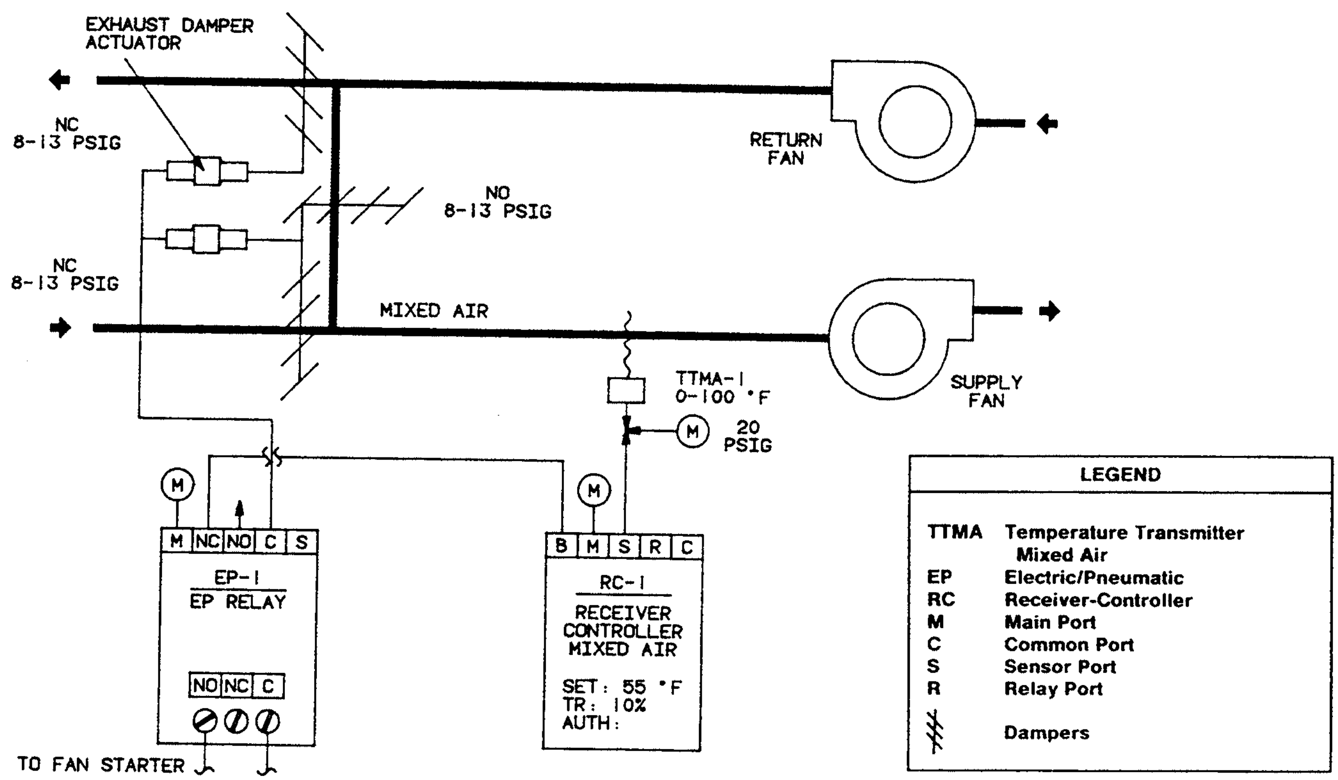


Figure 6-38
MIXED AIR CONTROL, ECONOMIZER

advantageous to maximize the use of outside air for cooling whenever possible. The type of economizer system will vary depending on geographical areas. In the past, some of the milder climate areas utilized no economizer system at all, or outside air dampers were in a fixed position at all times. The conversion to economizer systems has been a popular energy saving tactic. Pneumatic systems have tended to be more sophisticated because of their use in larger buildings, whereas most electric- or electronic-control systems generally did not include economizer systems if the buildings were built in the fifties and early sixties. A number of things can be done to enhance the operation of an economizer system. Several of these options are covered elsewhere in this handbook.

The operation of the economizer cycle shown in Figure 6-38 involves a mixed air transmitter that sends a signal to the direct-acting, mixed air receiver-controller, RC-1. This branch line signal is sent to the normally closed (NC) port of EP-1, which is connected in series with the fan starter circuit. When the fan is energized, EP-1 is energized, the NC and C ports are connected, and the branch line signal from RC-1 is sent to the outside, return, and exhaust damper actuators. When the fan is deenergized, the NC port of EP-1 is blocked, the C port is connected to the NO port, and the signal is exhausted to atmosphere, allowing the outside air, return air, and exhaust air dampers to close or open. As long as the supply fan is energized, the dampers will adjust in response to changing mixed air temperatures and will attempt to maintain a mixed air temperature of 55 °F.

.22 **Mixed Air Control, Economizer with High-Limit and Minimum-Position Control.** In this system (Figure 6-39) two functions are added to the economizer system. These functions are a high-limit control to deactivate the outside air intake if the temperature rises above a given set point, and a minimum-position switch so that the outside air damper will remain open at a minimum position to satisfy ventilation requirements in the building, irrespective of other conditions (such as low or high mixed air temperature during occupied hours).

The gradual switch (SP-1) that controls minimum position is capable of providing a fixed signal that is adjustable or passing a higher signal that is provided at port S-1. The set point on SP-1 is 9 psig. As long as the pressure at port S-1 (branch output of RC-1) is greater than 9 psig, this pressure will be transmitted out of port B to the NC port of EP-1. So long as EP-1 is energized, this pressure is passed on through C to the outside, return, and exhaust dampers, allowing them to adjust in response to the changing, mixed air temperature.

As outside air temperature increases, the mixed air controller, which is direct-acting, will increase its signal, adjusting the outside and exhaust dampers toward the open position and the return air damper to the closed position. If the outside air transmitter TTOA-1 senses a temperature rising above 70 °F, it will trigger the diverting relay (HL-1) that is used as a high-limit control, blocking the output of RC-1 and exhausting the common port out the NC port. This reduces the pressure at S-1 below 9 psig. The gradual switch (SP-1) will maintain a minimum 9 psig signal in the branch line, maintaining a minimum position on the outside, return, and exhaust dampers. In the example shown on Figure 6-39, the minimum position is shown as 8 psig (which corresponds to the range of the damper actuator) and the set point is 9 psig. In this case, 9 psig represents a movement of the outside air damper that will allow enough outside air to enter the building while the fan is running to meet minimum air requirements.

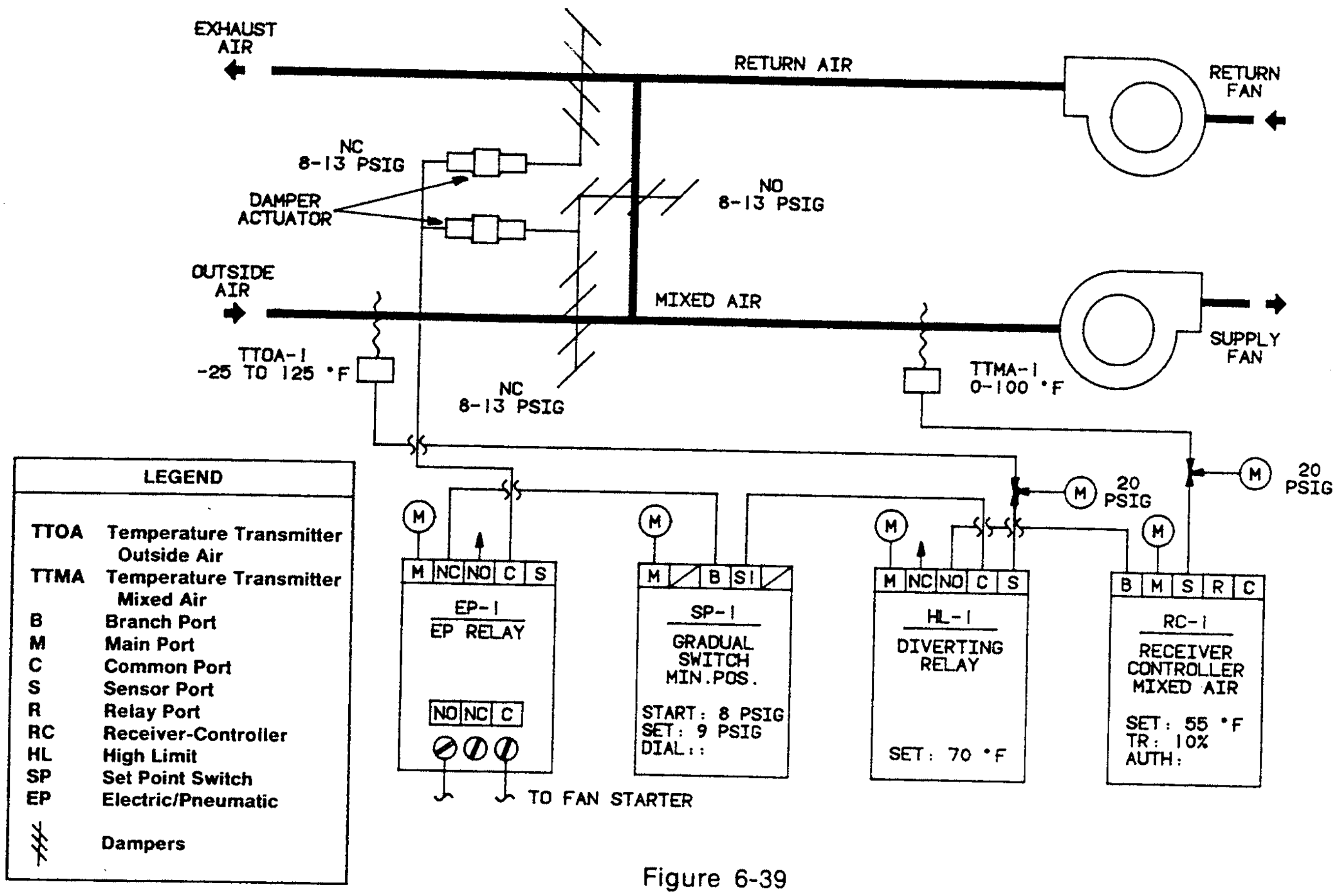


Figure 6-39

MIXED AIR CONTROL, ECONOMIZER WITH HIGH-LIMIT AND MINIMUM-POSITION CONTROL

.23 Mixed Air Control, Economizer with High-Limit, Minimum-Position, and Warmup Control. For this economizer application, warmup control has been added (Figure 6-40). Warmup control allows the building to warm up to the set temperature on morning startup before energizing the economizer system. Upon fan startup, EP-1 is energized as in the other systems and the signal from RC-1 (the mixed air controller) passes through HL-1 and SP-1 to the NC port of the diverting relay used as a warmup control (WU-1). Until the return air temperature sensed at TTRA-1 rises above the set point in the warmup relay which is 70 °F, the branch output of the mixed air controller is blocked at the warmup relay. Once the return air temperature rises above 70 °F, the relay switches and connects NC and C. This allows the branch signal to pass through to position the dampers in response to either the signal from the mixed air controller or, in the case of minimum position, in response to the gradual switch (SP-1).

.24 Mixed Air Control, Economizer with Enthalpy Changeover and Minimum-Position Control. In this application, an enthalpy-controlled changeover point is used to monitor whether there is free cooling available from the outside air.

This is in contrast to the previous systems where a fixed changeover point or high-limit control to lock out outside air was utilized. The amount of cooling energy needed is determined by the enthalpy content of the air which varies with both temperature and humidity. It is sometimes more economical to cool warmer outside air with a lower enthalpy content than it is to cool return air with a higher enthalpy content.

In Figure 6-41, a signal comparing relay, with two signal inputs from an enthalpy transmitter (hTOA-1) and a return air enthalpy transmitter (hTRA-1), is used. As long as the signal from hTOA-1 is less than the signal from hTRA-1, the NO and C ports of hL-1 are connected and the mixed air, receiver-controller provides a signal to position the dampers. When the outside air enthalpy rises above that of the return air enthalpy, hL-1 switches and blocks the NO port to exhaust the damper control signal back through C to NC which allows the outside, return, and exhaust dampers to return to the minimum position as governed by SP-1. The final

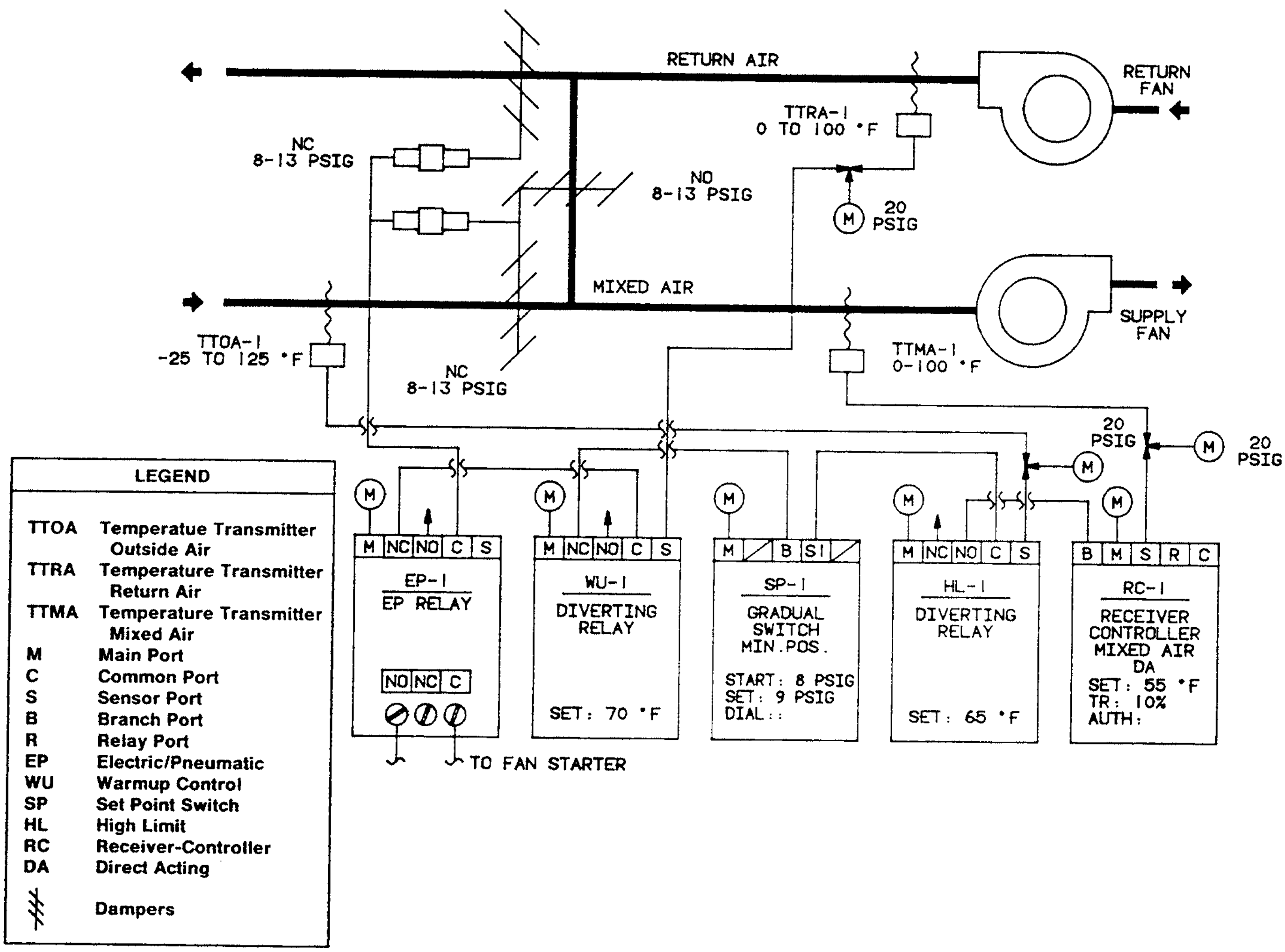


Figure 6-40

MIXED AIR CONTROL, ECONOMIZER WITH HIGH-LIMIT, MINIMUM-POSITION, AND WARMUP CONTROL

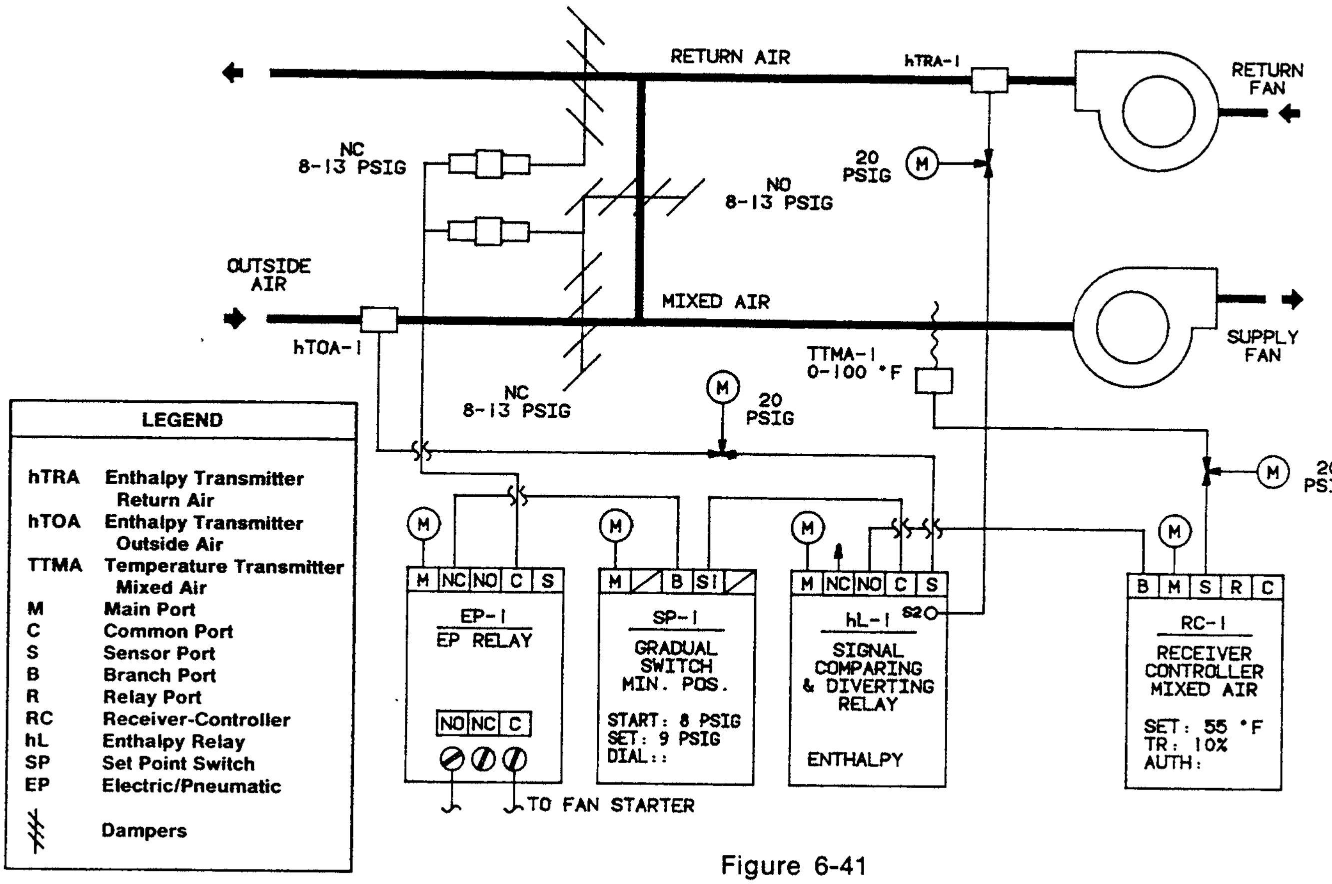


Figure 6-41

MIXED AIR CONTROL, ECONOMIZER WITH ENTHALPY CHANGEOVER AND MINIMUM-POSITION CONTROL

control, of course, is through EP-1, which is in series with the fan starter. When the supply fan is deenergized, EP-1 exhausts the control signal that positions the dampers to their normally closed or normally open position.

647.3 Unit Ventilator

Figure 6-42 depicts a unit ventilator. The unit ventilator is a self-contained unit except for a hot water supply from a central boiler. It does not rely on any central air handling system. It is generally located beneath the windows on an outside wall where the normally closed outside air dampers would bring in air for ventilation from the outside and the normally open return air dampers would be able to recirculate the return air after mixing it with the outside air.

When the fan is energized, the EP relay allows the thermostat signal to position the coil valve and the damper actuator. The fan draws the two air supplies through the heating coil to the space. The thermostat generally is direct acting and, as shown in Figure 6-42, is used to position a normally open heating valve. At the same time, whenever the fan is energized, the branch signal of the thermostat will also be fed to the damper actuators. In this application the damper actuator has a dual spring range of 1 to 4 psig and 8 to 12 psig.

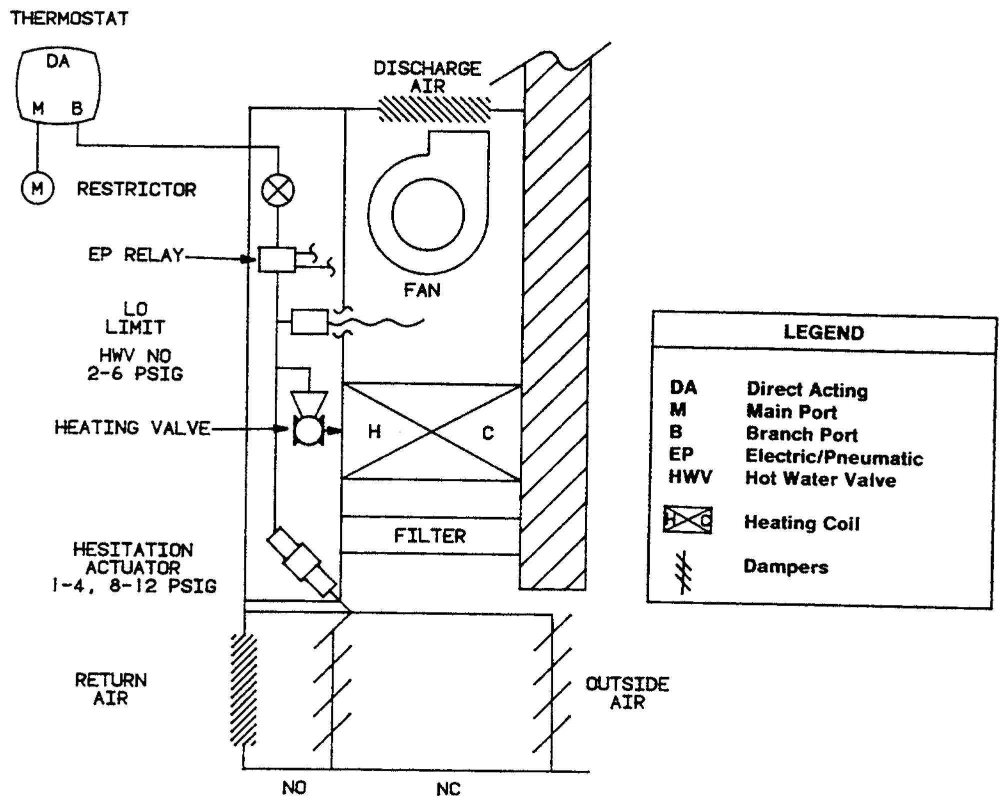


Figure 6-42
UNIT VENTILATOR

When the temperature in the space is below set point, the thermostat branch pressure will be low and the position of the dampers will be normally closed or at a minimum position to the outside air and open to return air. This will allow maximum recirculation of return air. At the same time the heating valve will be open, supplying additional heat to warm the space as the discharged air temperature is raised to achieve set point. As the room temperature approaches set point, the branch pressure will rise and throttle the normally open hot water supply valve toward the closed position. If the outside air temperature is quite cold and the discharged air temperature is lower than 55 to 60 ^{o}F, the low-limit control would bleed down the branch pressure, opening the heating valve and allowing the damper motor to close off outside air. This could occur regardless of the room temperature being satisfied.

The hesitation stroke, damper actuator utilizes two separate springs internally. The first of these is actuated between 1 and 4 psig. This provides a minimum amount of damper movement upon system startup. This allows the outside air damper to open to a minimum position to provide the required ventilation air. Nothing happens between 4 and 8 psig and the system operates on the return air. This is to prevent reheating of cold outside air as the hot water supply valve is closed through this range. After the room temperature is satisfied and the hot water supply valve is closed, the damper actuator will fully stroke between 8 and 12 psig, closing off the return air damper and opening the outside air damper to get a maximum amount of outside air to provide ventilation.

647.4 Multizone

.41 Multizone System with Hot and Cold Deck Control. This is a relatively simple system (Figure 6-43) utilizing two transmitters, two receiver-controllers, and a zone thermostat and damper actuator for each zone in the space. The receiver-controllers control three-way mixing valves that control flow to the hot and cold deck coils. Both receiver-controllers are direct-acting. The flow through the heating coil in the hot deck is normally open to heating, and the flow through the cold deck is normally closed to cooling. Spring ranges for these valves are selected for close-off ratings that would correspond to their application.

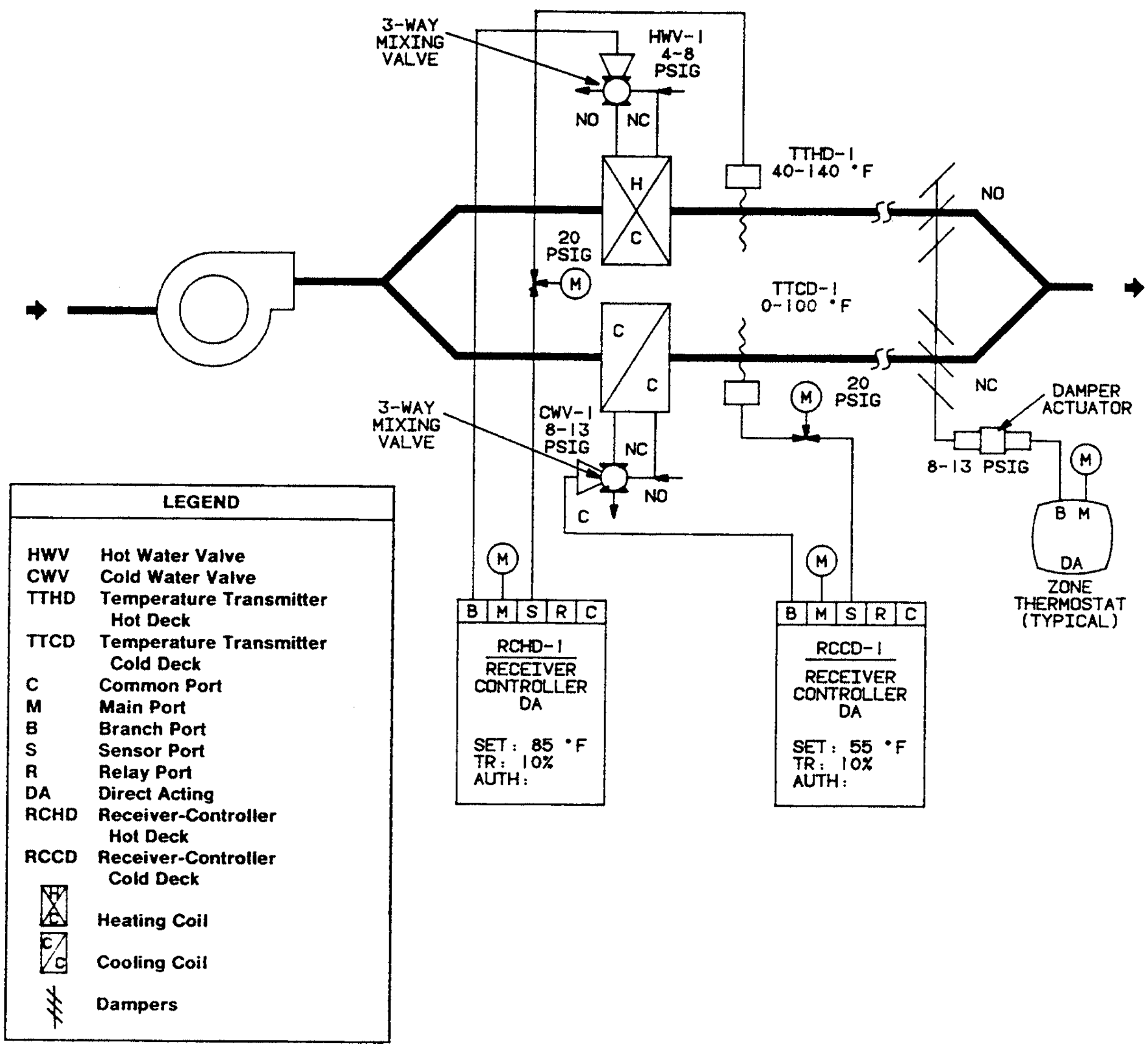


Figure 6-43

MULTIZONE HOT AND COLD DECK CONTROL

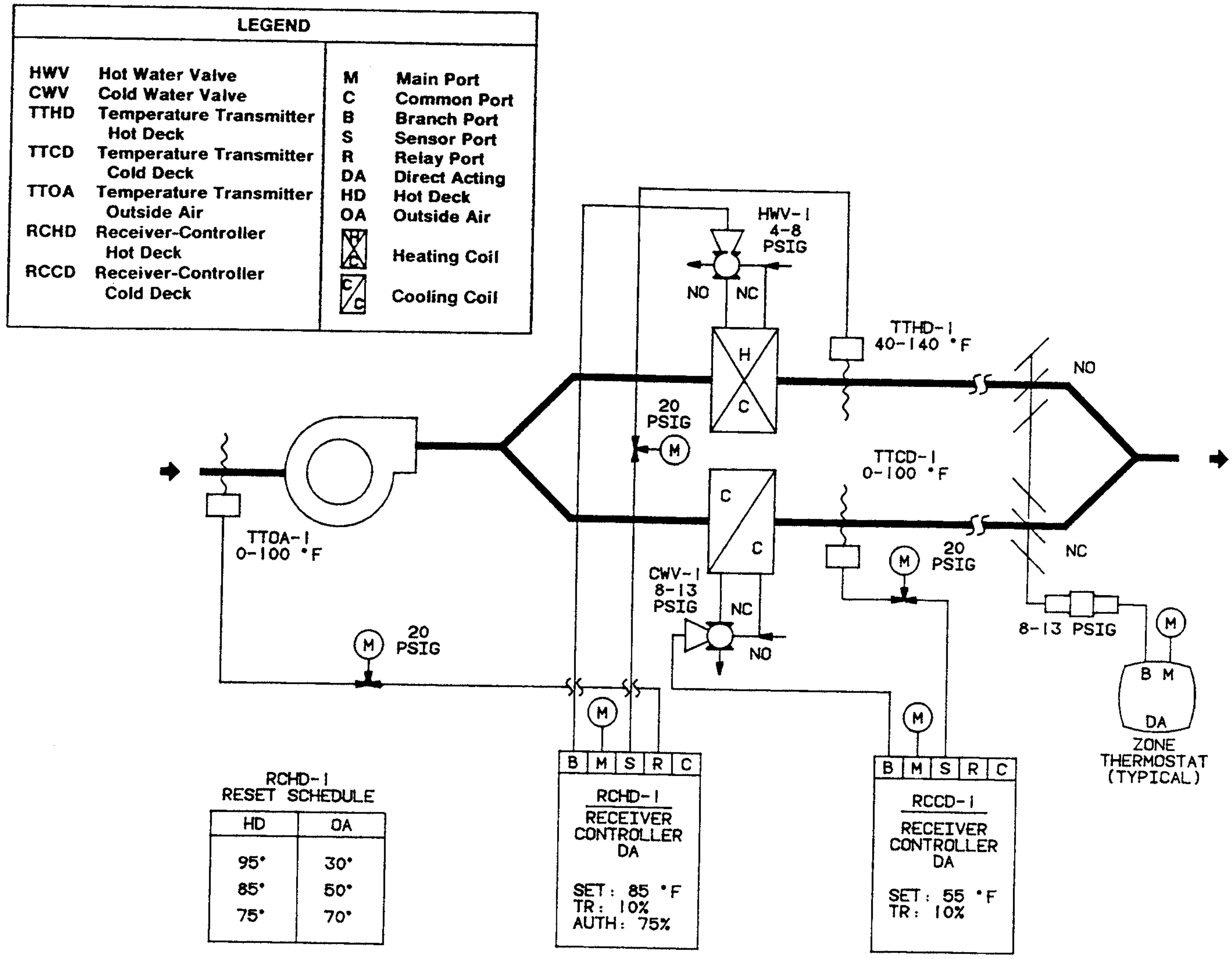


Figure 6-44

MULTIZONE HOT AND COLD DECK CONTROL WITH HOT DECK RESET

.42 **Multizone System with Hot and Cold Deck Control with Hot Deck Reset.** This system (Figure 6-44) is essentially the same as the system in Figure 6-43, with the addition of a temperature transmitter in the outside air duct. The signal from the temperature transmitter is piped to port R of the receiver-controller (RCHD-1). The reset schedule shown represents the design temperature ranges of 30 to 70 °F outside air temperature. Over this outside air temperature range, it is determined that a range of from 75 to 90 °F hot deck temperature will be sufficient to offset the heat losses that these temperature changes cause. The authority setting of this application works out to be 75 percent, utilizing a 10 percent throttling range with the transmitters as shown.

.43 **Multizone System with Hot and Cold Deck Control with Hot and Cold Deck Reset.** In this system (Figure 6-45) the additional step of adding cold deck reset from space temperature has been taken so that cold deck temperatures are maintained only at a level required by demand in the various zones. A high/low

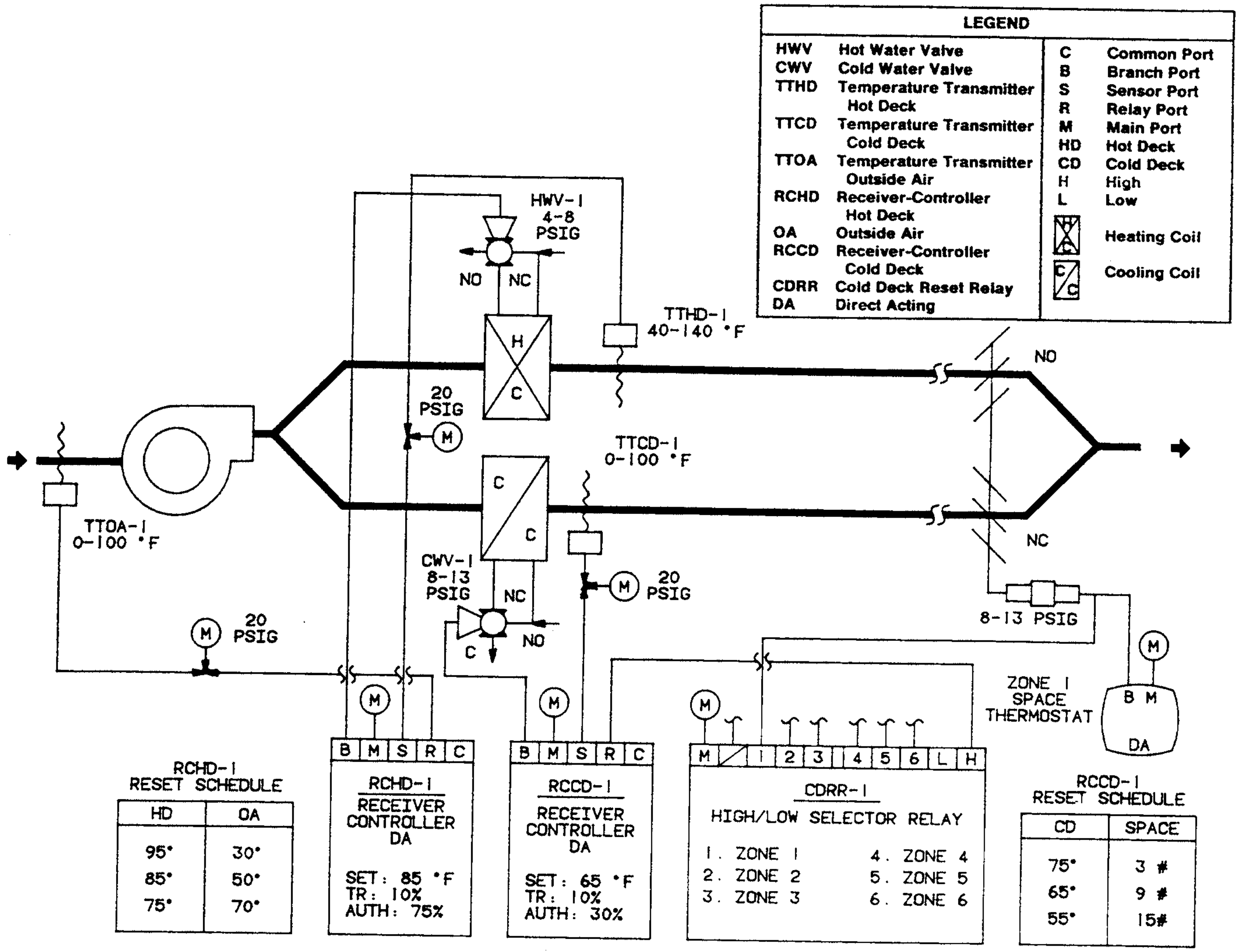


Figure 6-45

MULTIZONE HOT AND COLD DECK RESET

multi-input selector relay is included which will accept the branch input from up to six individual zones and pass through the highest input to reset RCCD-1 per the cold deck reset schedule.

This type of system allows the temperature of the cold deck to be reset upwards as demand decreases in the space. The zone of highest demand is represented by the highest output passed through to reset the receiver-controller so that the system will effectively compensate for worst case demand. The advantage here is that the cold deck supply temperature may be reset upwards to reduce cost of cooling, as space demand decreases.

647.5 Hot and Cold Duct or Dual-Duct System Control

This system (Figure 6-46) is very similar to the basic hot deck/cold deck or multizone control that has already been described. The primary difference is in the delivery of the hot and cold air supply to the spaces. Dual-duct systems are relatively rare and are generally considered not to be energy

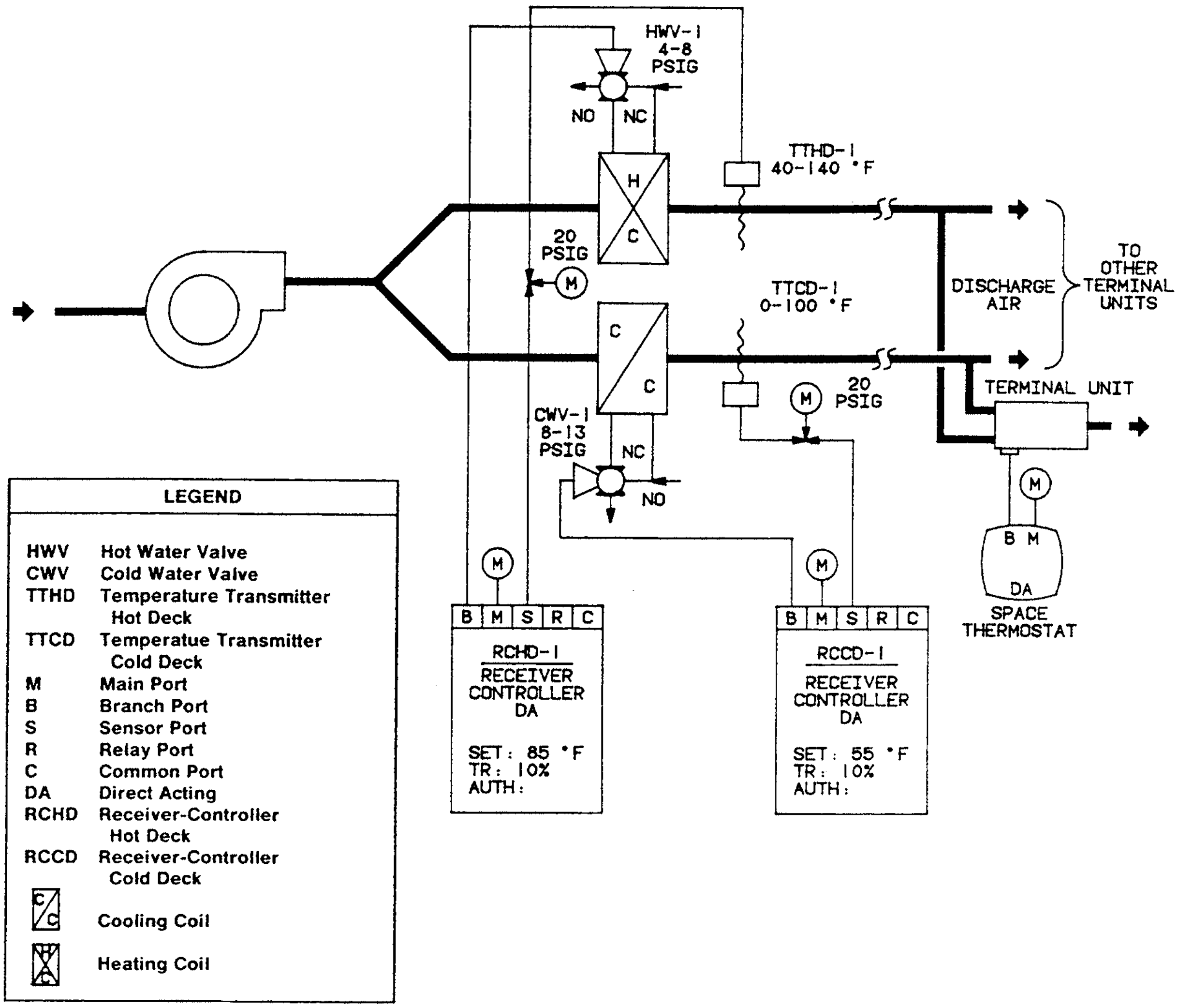


Figure 6-46

DUAL-DUCT CONTROL

efficient. They were originally designed to provide a continuous supply of hot deck temperature and cold deck temperature to each space. The terminal units for each space would mix these two air supplies as necessary to provide a discharge air temperature that would satisfy space conditions. These systems are used very rarely today; many older systems have been retrofitted to lock out the hot or cold deck during the inappropriate season. In doing so, the necessity of reheating or recooling air is eliminated.

Some of these systems may also utilize hot deck reset (probably the most common) and, occasionally, cold deck reset. These functions most probably would have been added on as an energy-saving measure. As stated earlier, most of these systems predate the common application of both of these functions.

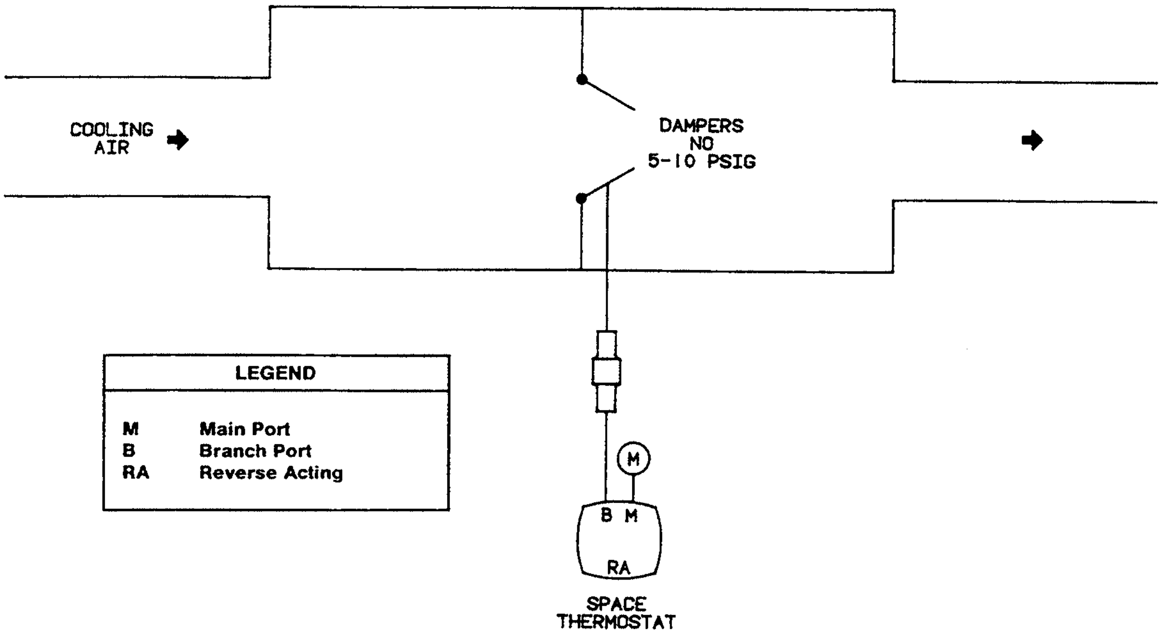


Figure 6-47

VAV TERMINAL UNIT

647.6 Variable Air Volume (VAV) Terminal Unit

.61 **Terminal Unit, Variable Air Volume (VAV).** The terminal unit shown in Figure 6-47 is a typical variable air volume (VAV) unit. In the example shown, the terminal is supplied with cooling air and the terminal dampers are in the normally open position. The thermostat controlling the space temperature is reverse-acting. The damper position is normally open. As the temperature rises, the terminal dampers open to allow greater flow into the space. This terminal could also be supplied with warm air and utilize a direct-acting thermostat that would close the dampers to minimum on a rise in temperature. Units of this type usually have a mechanical stop for minimum and/or maximum volume adjustment. Volume varies as the inlet duct static pressures vary.

.62 **Terminal Unit, VAV with Reheat.** This is a variable volume, throttling-type terminal as previously discussed, except a reheat coil and hot water valve are included to operate in sequence with the volume damper. In Figure 6-48, a reverse-acting thermostat and a normally open volume damper are being used. As the temperature decreases, the volume damper is closed by an increase in branch line pressure. As the pressure continues to rise in the branch line, the VAV unit goes to a minimum flow which is mechanically set. As the pressure continues to rise, the normally closed hot water valve starts to open. The hot water valve will throttle to full flow upon sufficient demand in the space and, on a decrease in demand for

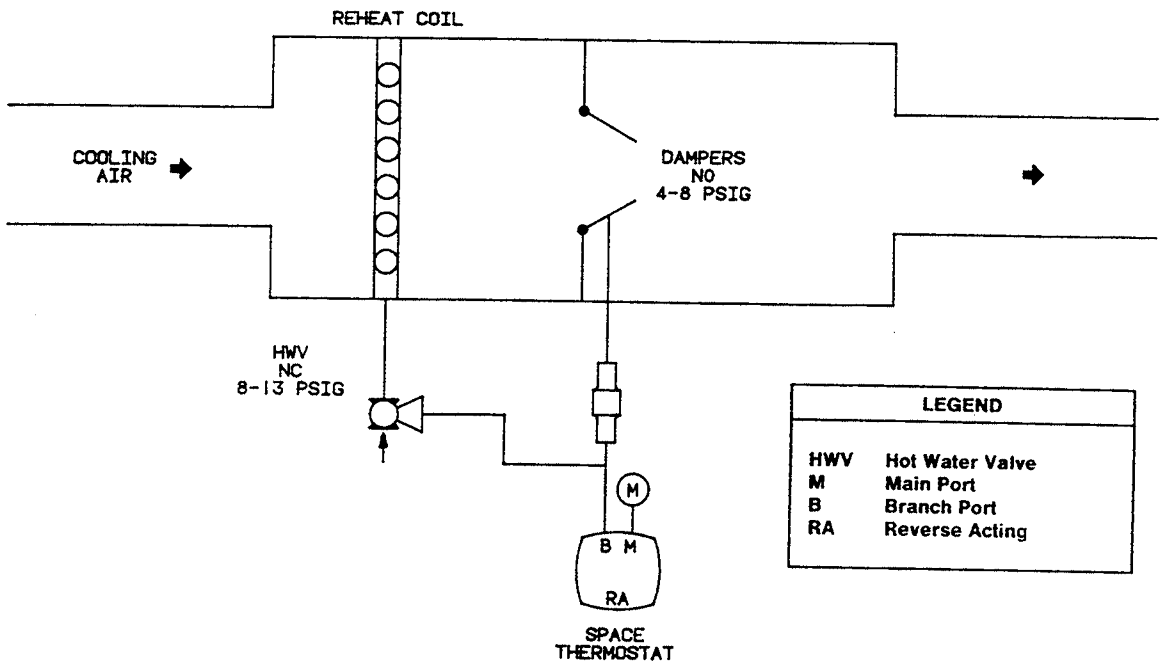


Figure 6-48

VAV TERMINAL UNIT WITH REHEAT

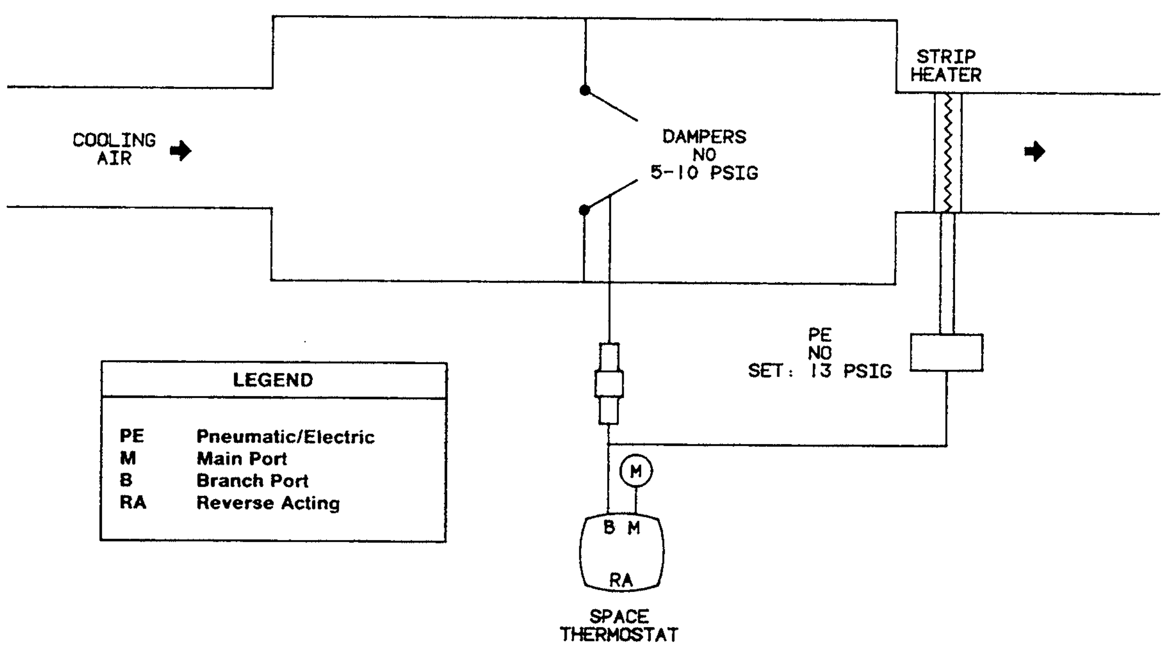


Figure 6-49

VAV TERMINAL UNIT WITH STRIP REHEAT

heat, will throttle toward the closed position. It will be fully closed before the terminal unit starts to open to allow a greater flow of cooling air to the space.

.63 **Terminal Unit, VAV with Strip Reheat.** In Figure 6-49, a strip heater in the duct is used. It is controlled in sequence with the VAV damper. The reverse-acting thermostat responds to an increase in space temperature by decreasing the branch line pressure, thus opening the VAV box to increase flow to meet demand in the space. As space temperature decreases, output of the controller increases, driving the terminal dampers toward the minimum position. If this action is not sufficient to maintain space temperature at a comfortable level, decreasing temperature will cause the room thermostat to increase the branch line pressure. This will close the normally open contacts in the PE switch which is controlling the electric strip heater. This will reheat the incoming air to the space until the space temperature reaches set point.

.64 **Variable Volume Diffuser.** This is a slightly different type of terminal unit (Figure 6-50) with the terminal unit being part of the space diffuser. This unit would encompass mechanical limits for minimum and maximum volume and, as shown, would be normally open to cooling with a reverse-acting thermostat.

.65 **Terminal Unit, VAV with High-Limit Control.** This terminal unit (Figure 6-51) is controlled by a thermostat in the space to be conditioned and a constant volume/VAV controller. These sense flow through the terminal unit. The controller contains a built-in high-limit control that limits flow through the terminal unit to a maximum setting established by the manufacturer (or upon application in the field by air balance specialists).

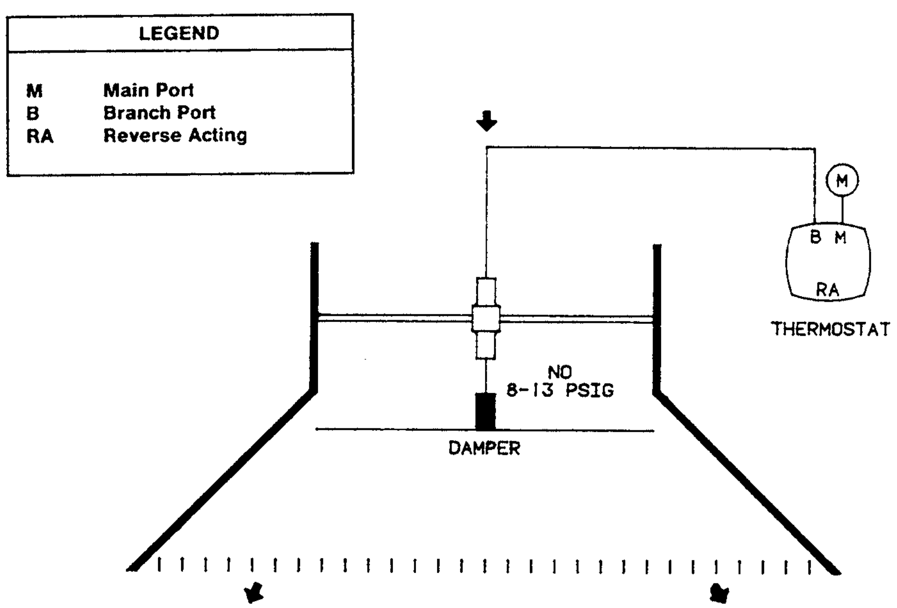


Figure 6-50
VAV DIFFUSER

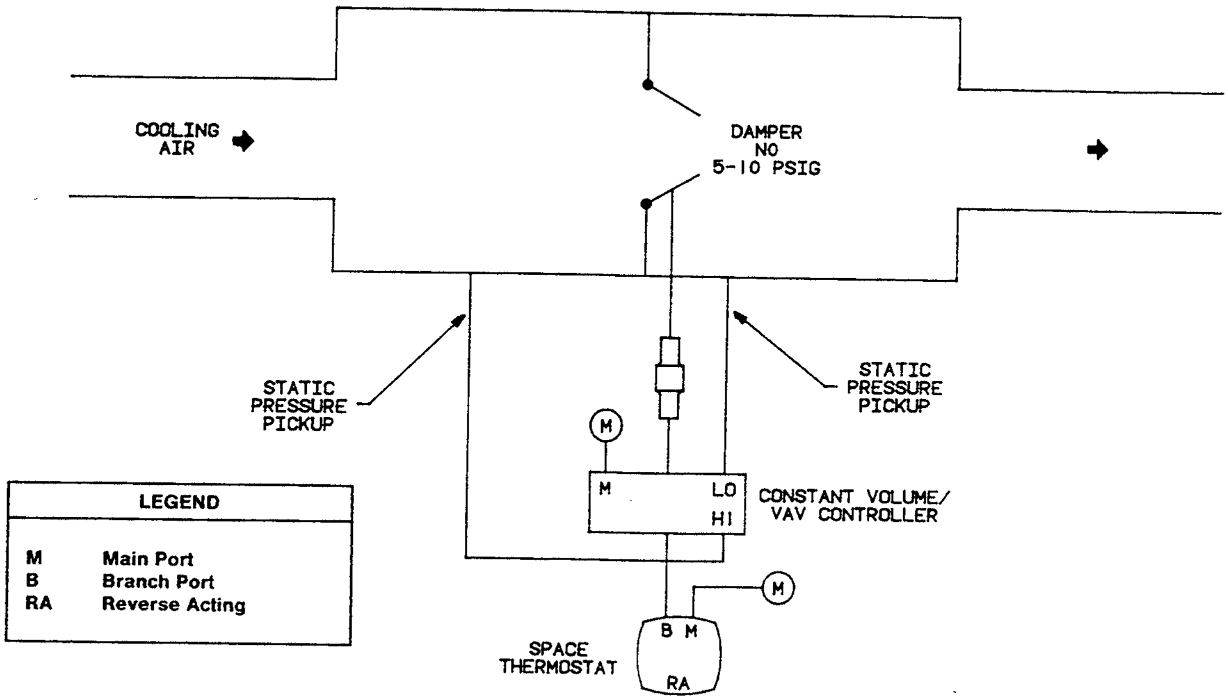


Figure 6-51

VAV TERMINAL UNIT WITH HIGH LIMIT

The terminal unit is supplied with cooling air and utilizes a normally open damper and a reverse-acting thermostat. The space thermostat controls the action of the damper. As the space temperature increases, the branch line pressure falls allowing flow to increase through the terminal unit. As flow increases, the sensed pressure from the low and high static pressure pickups is sensed and, at the predetermined high limit, the direct action of the controller will take over through the high select relay built into the controller. The constant volume/VAV controller will maintain flow at that fixed maximum setting.

This type of terminal unit control responds to changing supply pressures. The duct supply pressure may vary either upward or downward in response to demand in other zones within the building. If demand increases in other zones of the building, other terminals will open and decrease the total available static pressure. The constant volume controller will respond by allowing the actuator to open further and add air volume into the space to meet the desired demand.

The other situation that may occur is an increase in static pressure due to one or more terminal units closing down on a decrease in demand in other areas of the building which increases the static pressure and, therefore, increases flow through other terminal units. The static pressure sensors will pick up this increased flow and compensate for it by closing the terminal damper in each unit to maintain flow at the preset high limit.

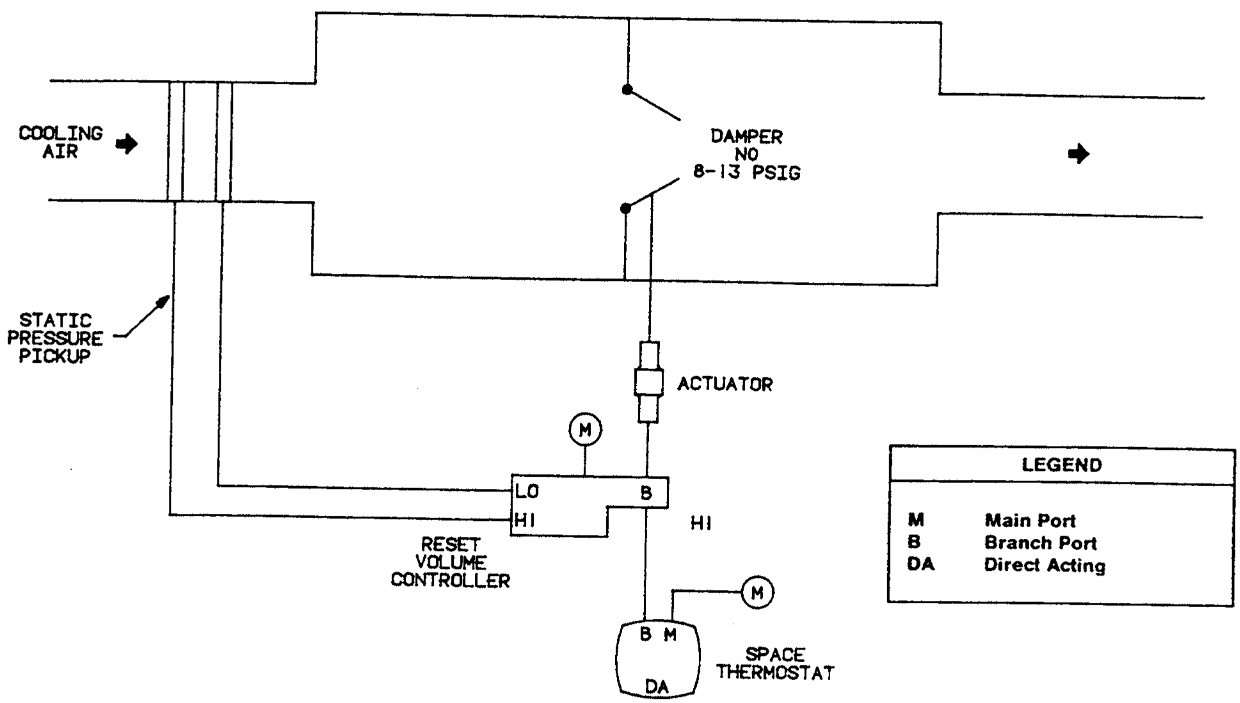


Figure 6-52
VAV PRESSURE INDEPENDENT TERMINAL UNIT

.66 **Terminal Unit, VAV Pressure Independent.** This type of terminal unit (Figure 6-52) utilizes a slightly different type of volume controller that maintains a constant volume of flow into the space to be conditioned in response to space demand. The controller used is a reset volume controller with a control output range of 8 to 13 psig. This matches the spring range of the actuator that it is controlling. The reset volume controller has minimum and maximum flow set points. The device in this particular application is a direct-acting controller used in conjunction with a direct-acting space thermostat. The space thermostat resets the set point of the controller up or down between 8 to 13 psig in response to changing space temperature. As the space temperature goes up, the branch line pressure from the thermostat goes up, resetting the set point of the controller downward to allow a greater volume of air to flow through the terminal unit into the space. At any given control point the volume controller will respond to changes in inlet flow, opening or closing the damper to maintain a flow rate that corresponds to the set point needed to satisfy space temperature.

This type of system is rarely used as a retrofit application, but has become quite common in new applications. The primary reason for it not being used in a retrofit situation is that the action of the thermostat and actuator must be changed in most applications to be used with this type of controller.

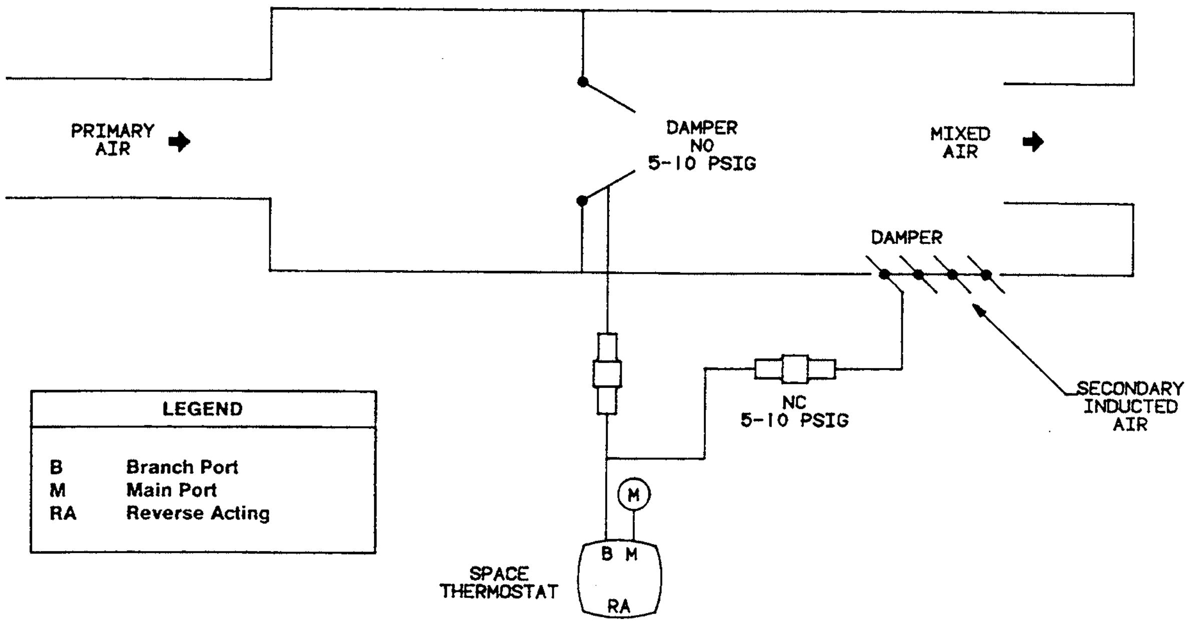


Figure 6-53
VAV INDUCTION BOX

647.7 VAV Induction Unit

.71 VAV Induction Box. Induction units as shown in Figure 6-53 use primary system air discharged through the terminal unit, and secondary air inducted from the controlled space.

A typical unit is shown with thermostatically controlled operators varying the primary and secondary dampers. On a demand for less cooling, the primary air dampers throttle, reducing primary air volume. The inducted air dampers are simultaneously opened. Primary air discharges into a mixing section while inducting return air flow from the surrounding space. Mixed air is redirected into the supply duct and out of the diffuser.

.72 VAV Induction Box with Reheat. Figure 6-54 is essentially the same as the induction box described in 647.71, but with the important additional feature of a reheat coil in the primary air supply. This type of unit is used primarily in perimeter areas. It provides additional heat capability in those areas that have a greater demand for heat, such as perimeter zones.

Note that the actuator spring ranges are slightly different here to accommodate the sequencing of the hot water supply valve. Instead of 5 to 10 psig actuators, they have a range of 4 to 8 psig so that the normally open primary volume damper is at its minimum-flow position, and the secondary air dampers are fully open before the normally closed water supply valve starts to open.

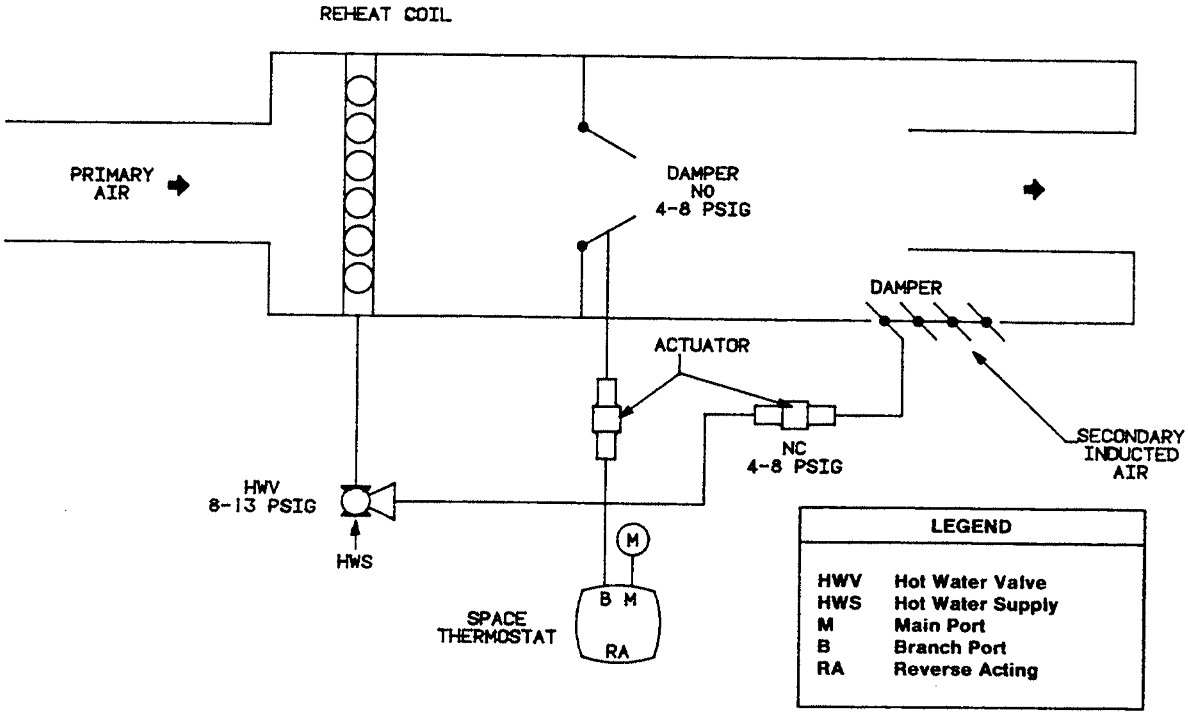


Figure 6-54

VAV INDUCTION BOX WITH REHEAT

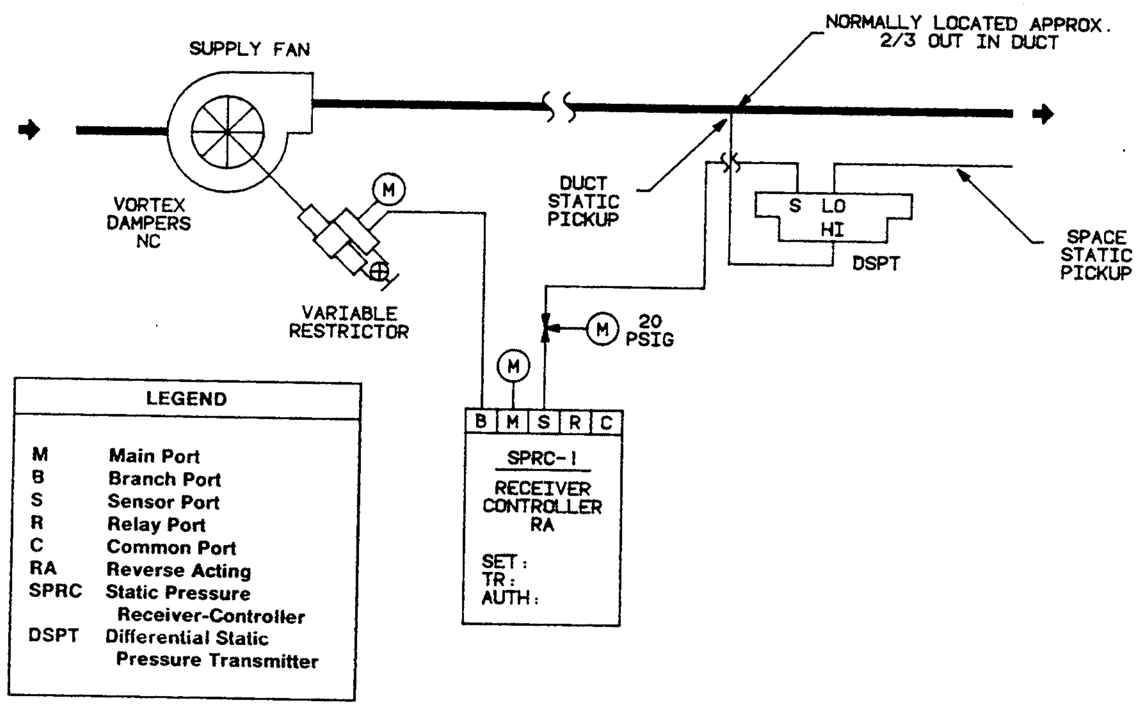


Figure 6-55

SUPPLY FAN VOLUME CONTROL

647.8 Supply Fan Volume Control

.81 General. The purpose of fan volume control is to maintain a preset system static pressure. As shown in Figure 6-55, static pressure is sensed with a differential static pressure transmitter by referencing space static pressure and a point two-thirds downstream from the fan in the supply duct. The transmitter signal is sent to the reverse-acting receiver-controller, which moves the normally closed supply fan vortex damper to maintain the desired static pressure level.

A common problem with the fan volume control is that the vortex vanes may overshoot the control point. Some systems are so sensitive that hunting problems may occur even though the receiver-controller is set at its widest proportional band setting. In such cases it is recommended that a variable restrictor be used between the branch output of the receiver-controller and the damper actuator. This will slow the actuator response until stable control is achieved.

.82 Supply Fan Volume Control with Reset. A major consideration in controlling static pressure is hunting as the controller seeks its set point. On the other hand, if the throttling range is too wide, an objectionable offset to the control point could occur.

With the addition of an integral reset relay as shown in Figure 6-56, the offset problem can be substantially overcome. This relay (RR-1) provides integral reset to the proportional control of the receiver-controller. Although the offset may not be eliminated totally, it will be reduced substantially.

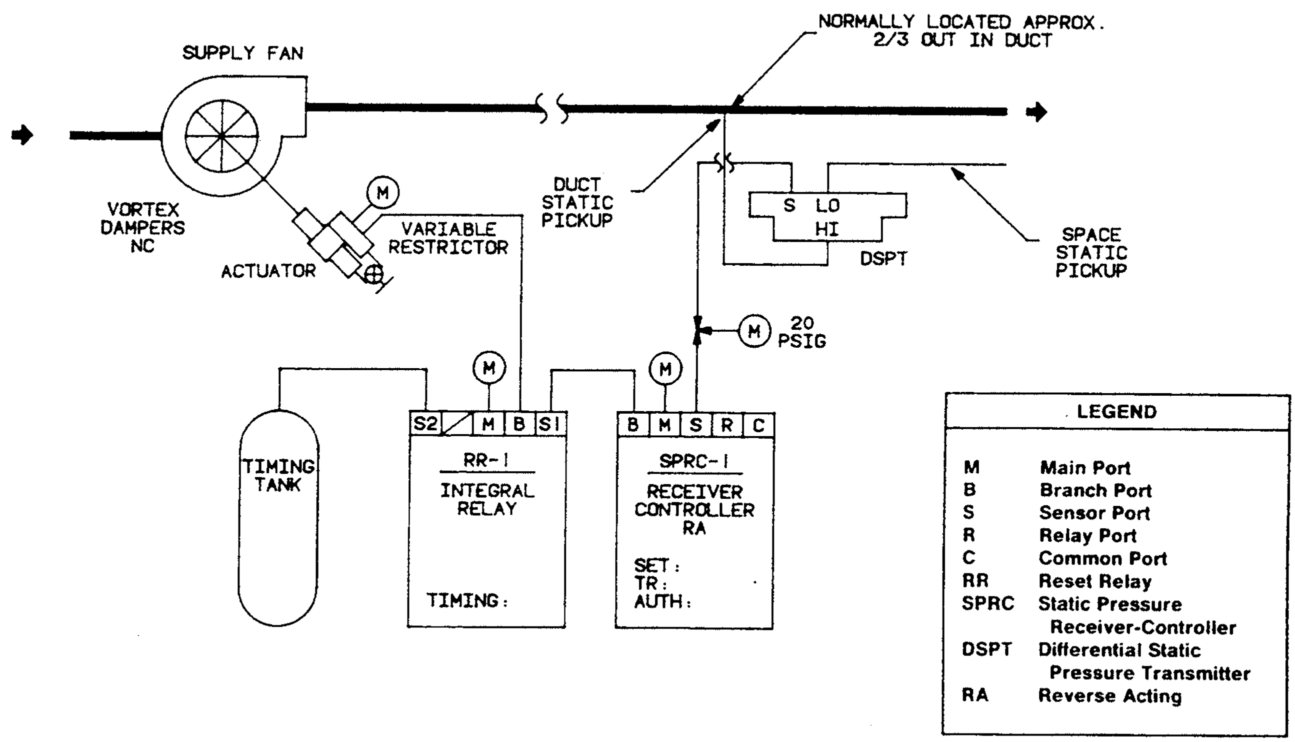


Figure 6-56

SUPPLY FAN VOLUME CONTROL WITH RESET

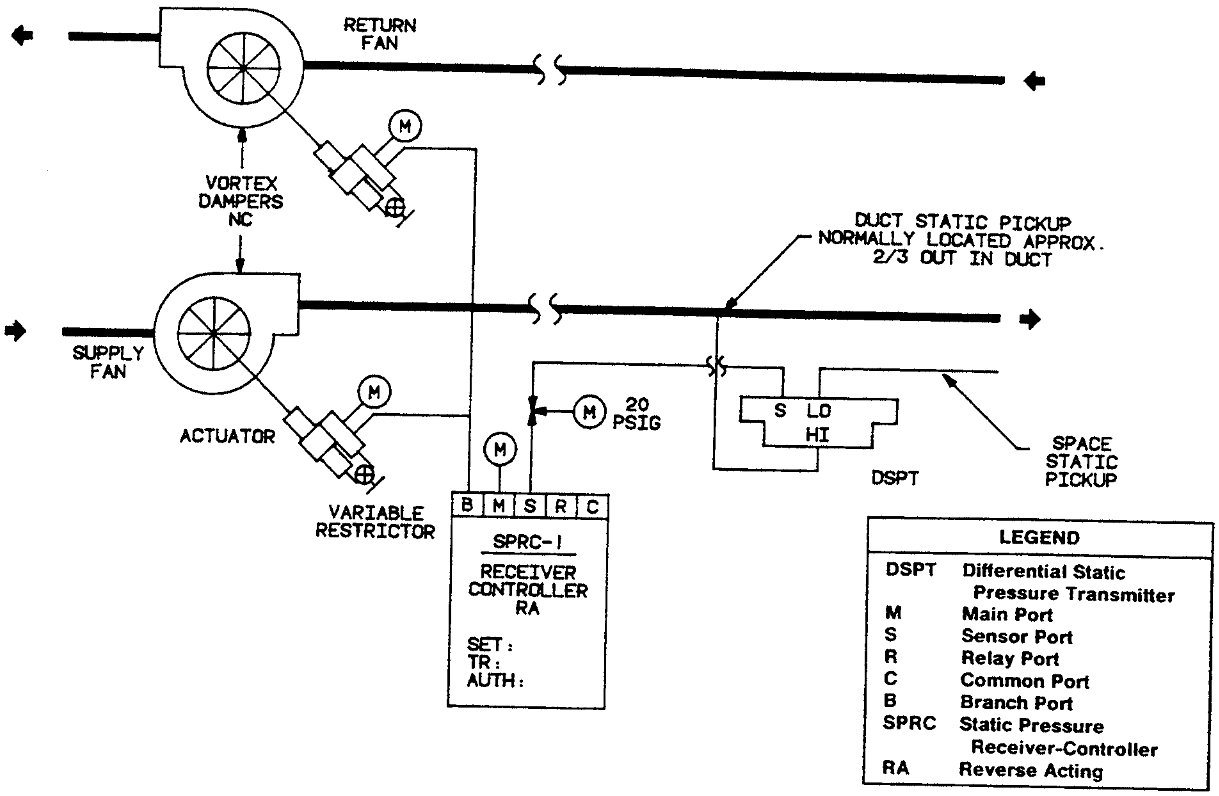


Figure 6-57

OPEN LOOP SUPPLY AND RETURN FAN CAPACITY CONTROL

As explained in the example in Section 647.81, the problem remains that the vortex vanes may overshoot their control point. By placing a variable restrictor between the branch output of the integral relay and the actuator, the actuator movement will slow in order to achieve stable control.

647.9 Open Loop Supply and Return Fan Capacity Control

.91 **General.** This control system (Figure 6-57) is similar to the basic supply fan capacity control system, except that the control signal moves the vortex dampers on the supply and return fans. The objectives are to maintain the supply static pressure at a preset level as system demand varies, and to maintain a fixed volume differential between the supply and return fans to maintain building static pressure at a fixed level. This method is widely used because of its simplicity.

The differential static pressure transmitter signal is sent to a reverse-acting receiver-controller which moves the supply fan vortex damper to maintain static pressure at a preset level as system demand varies. The receiver-controller also moves the return fan vortex damper to maintain a relatively constant cfm differential between the supply and return fans. This is accomplished by using a damper actuator with a positive positioner on it to adjust the start point and effective spring range of the return fan vortex damper at minimum and maximum flow conditions. This adjustment ensures that the desired cfm differential is present at both ends of the demand curve and assumes that the fan curves are matched closely enough to minimize errors as the flow varies from maximum to minimum.

The accuracy of this control method in maintaining a fixed differential between supply and return fans depends on linear damper characteristics and matching fan curves. This may be difficult to obtain. However, this mismatch usually is not usually serious if the fans are of the same type. The fans are sized to operate at approximately the same percent of flow on their curves, and system flow reduction is limited to approximately 50 percent.

If the system load varies significantly between major zones in the supply system, the return system resistance may not vary in direct proportion to supply system resistance. This control method does not sense the effect of resistance variations between supply and return systems. Therefore, the building pressure may vary when major load variations occur.

Again, on this system, it is recommended that variable restrictors be installed between the positioner and the damper actuators to slow down response and aid in balancing the system.

.92 **Open Loop Supply and Return Fan Capacity Control Reset.** Figure 6-58 is a duplication of the example in 647.91 with the addition of reset control.

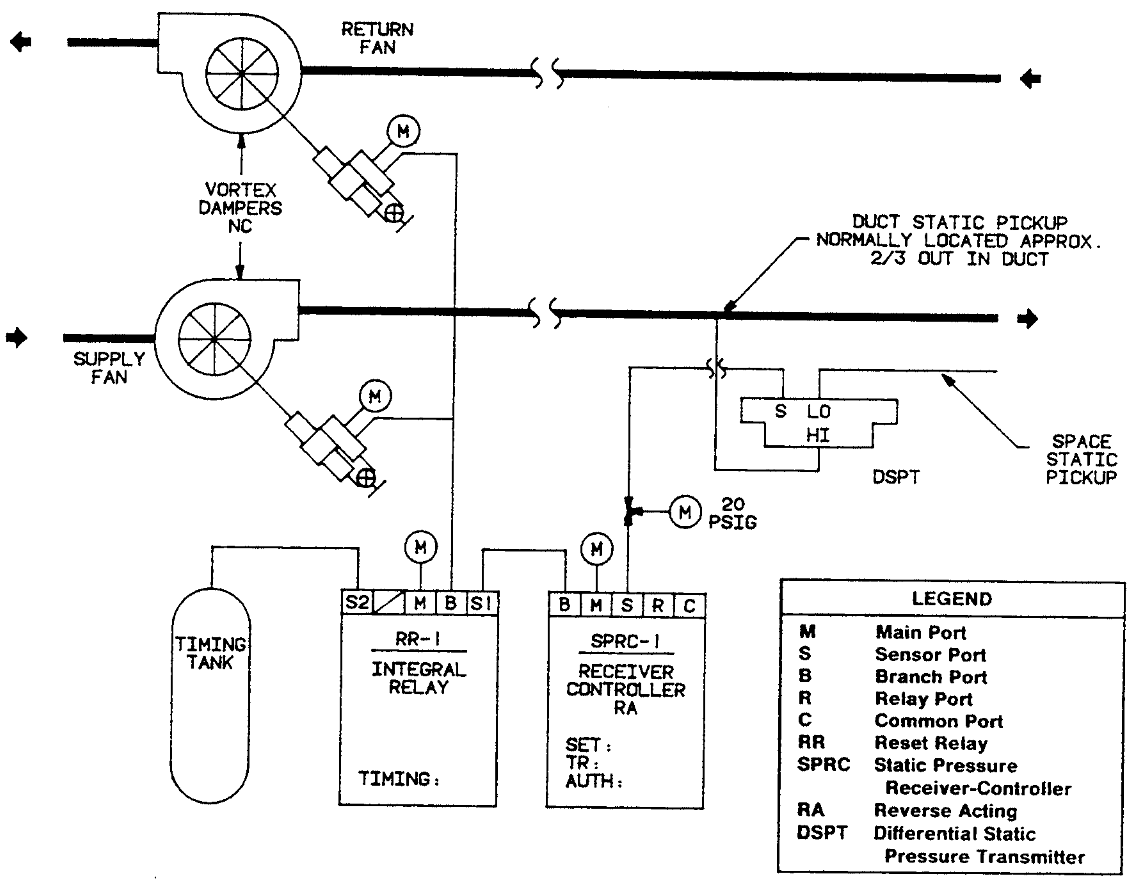


Figure 6-58

OPEN LOOP SUPPLY AND RETURN FAN CAPACITY CONTROL RESET

Again, this is accomplished by adding the integral reset relay (RR-1).

As in the previous capacity control sequences, it is imperative that system stability be obtained before adding reset function.

648 ENERGY MANAGEMENT SYSTEMS (EMS)

648.1 General

In large central air-conditioning installations, environmental conditions are monitored and controlled by energy management systems. These systems provide total building automation and energy management functions. Standard features are as follows:

a. Comprehensive energy management

b. High-level programming language

c. Maintenance management

d. On-line data base generation

e. Trend logging

f. Continuous self-diagnostics

g. Multilevel password access

h. Universal analog inputs

i. Alarm actions with message text

j. Auto restart after power failure

k. Forty-eight hour, rechargeable battery backup to protect programs

Time of day scheduling, duty cycling, start/stop time optimization, electrical demand limiting, night temperature setback/setup, and outside air optimization are normally addressed by energy management systems. Several of the manufacturers provide access to IBM computers for high-level operator interface.

648.2 General Monitoring System

In large central air-conditioning installations, postal facilities are currently being modified with the General Monitoring System (GMS). Basically, GMS is a microprocessor-controlled computer that interfaces with various manufacturers' heating, ventilating, and air-conditioning controls. The GMS, through various peripheral control devices, monitors and controls large facility HVAC. GMS installations on an individual basis have the ability to schedule various air-handler requirements, such as unoccupied spaces, scheduled downtime, holiday, etc.

650 PUMPS

651 CENTRIFUGAL PUMP THEORY

Centrifugal pumps use centrifugal force to develop a pressure rise for moving a liquid. (See Figure 6-59).

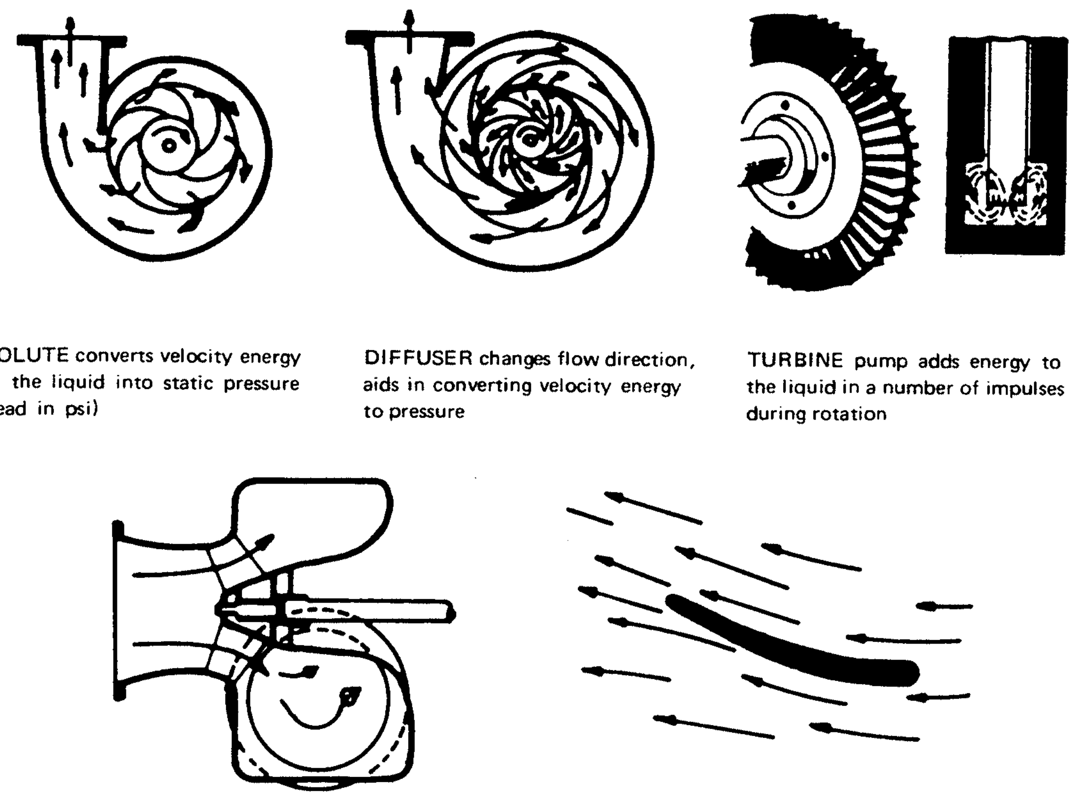
652 TYPES OF CENTRIFUGAL PUMPS

652.1 General

Many types of centrifugal pumps with considerable variation in design and construction exist. However, alterations are made to five basic types--volute, diffuser, mixed-flow, axial-flow (propeller), and turbine or regenerative--to suit special conditions.

652.2 Volute Pump

The volute pump is so named because the impeller rotates in a spiral-shaped housing, called the volute. In this pump, fluid is discharged by the impeller into a progressively expanding spiral casing that is proportioned to



VOLUTE converts velocity energy of the liquid into static pressure (read in psi)

DIFFUSER changes flow direction, aids in converting velocity energy to pressure

TURBINE pump adds energy to the liquid in a number of impulses during rotation

MIXED-FLOW units use both centrifugal force and lift of vanes on the liquid

PROPELLER pump develops most of its head by propelling action of vanes on liquid

Figure 6-59

CENTRIFUGAL PUMP THEORY

gradually reduce fluid velocity. Thus, velocity energy changes to pressure energy in the volute.

The majority of centrifugal pumps built in the United States today are volute pumps. These include horizontal and vertical pumps, and single stage or multistage pumps for wide ranges of flow and pressure.

652.3 Diffuser Pump

The diffuser pump uses nearly the same housing as the volute pump but has stationary guide vanes built into the housing and surrounding the runner. These gradually expanding passages change the direction of fluid flow and convert velocity energy to pressure energy. This pump was originally more efficient than the volute pump; however, efficiency of both types is now about equal. Diffuser pumps have many uses as multistage high-pressure units.

652.4 Mixed-Flow Pump

Mixed-flow pumps are ideal for low-head, large-capacity applications. Although some horizontal units are built, the pumps are usually vertical with a single impeller. Mixed-flow units develop pressure partly by centrifugal force and partly by the force of guide vanes on the fluid.

652.5 Axial-Flow Pump

Axial-flow units, often called propeller pumps, develop most of their head by the lifting action of guide vanes. These pumps are usually vertical and best suited for low heads and large capacities. Axial-flow pumps direct the fluid along the same axis as the pump shaft.

652.6 Turbine Pump

Turbine, or regenerative, pumps add energy to the fluid in a number of impulses, resulting in a high discharge velocity. Liquid is picked up by the impeller vanes and whirled at a high velocity for nearly one revolution in an annular channel in which the impeller turns. Turbine pumps are either horizontal or vertical and are usually used to pump clear fluids at high head pressure and low to medium capacity.

653 CENTRIFUGAL PUMP STRUCTURE

653.1 Basic Components

All centrifugal pumps are constructed with the same basic components: an impeller to increase the velocity of the fluid; a casing to contain and direct the flow of the fluid; a shaft on which to mount and rotate the impeller; bearings to support and permit free rotation of the shaft; a seal or stuffing box and lantern rings to keep the liquid in or the air out of the casing; wear rings in the casing and on the impeller to reduce costly wear on these components; and shaft sleeves to protect the shaft from wear, corrosion, or erosion. Although all pumps using centrifugal force as the moving force are classed in the broad centrifugal pump class, the intended application is a major factor in impeller and casing design, materials used, and other mechanical and hydraulic features.

653.2 Impellers

Impellers are classified according to their structure, how the liquid enters, and the detail of the vanes. Figure 6-60 shows seven different types of impellers:

a. Open. An impeller with relatively small shrouds and vanes attached to a central hub

b. Semi-Open. An impeller with shroud or wall on one side only

c. Closed. An impeller, single suction, with shrouds on both sides to enclose liquid passages and with liquid inlet on one side only

d. Closed. An impeller, double suction, similar to Section 653.2c with liquid inlets both sides

e. Mixed-flow.

f. Axial-flow.

g. Mixed-flow.

653.3 Casings

.31 Function. The pump casing performs three basic functions:

a. Directs the flow of liquid in the volute

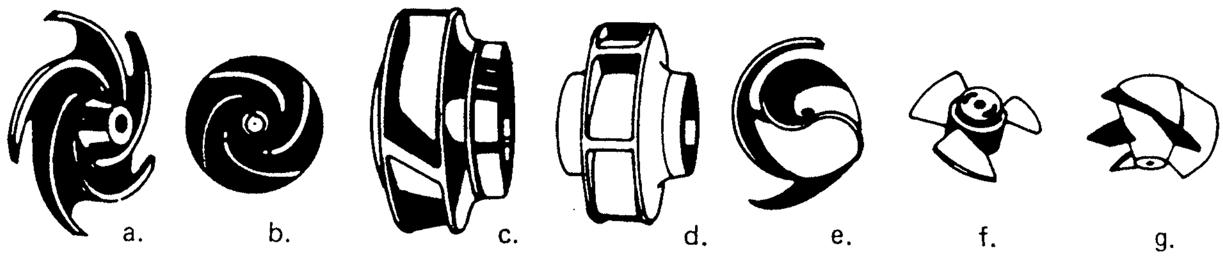


Figure 6-60
PUMP IMPELLERS

b. Provides a space to house the impeller

c. Supports the impeller and impeller shaft

.32 **Types.** Casings are manufactured in three basic types:

a. Horizontally-Split Casings. Both suction and discharge ports are in the lower half of the casing, and the upper half lifts off for easy inspection and repair.

b. Vertically Split Casings. Vertically split pumps have a radial separation between the casing and suctio head, or between the casing and frame. The pumps may be multistage with enclose or open impellers.

c. Barrel Casings. Barrel casings are used on high-pressure diffuser and volut pumps. An inner casing fits in an outer barrel. Discharge pressure acting on the inner case provides sealing.

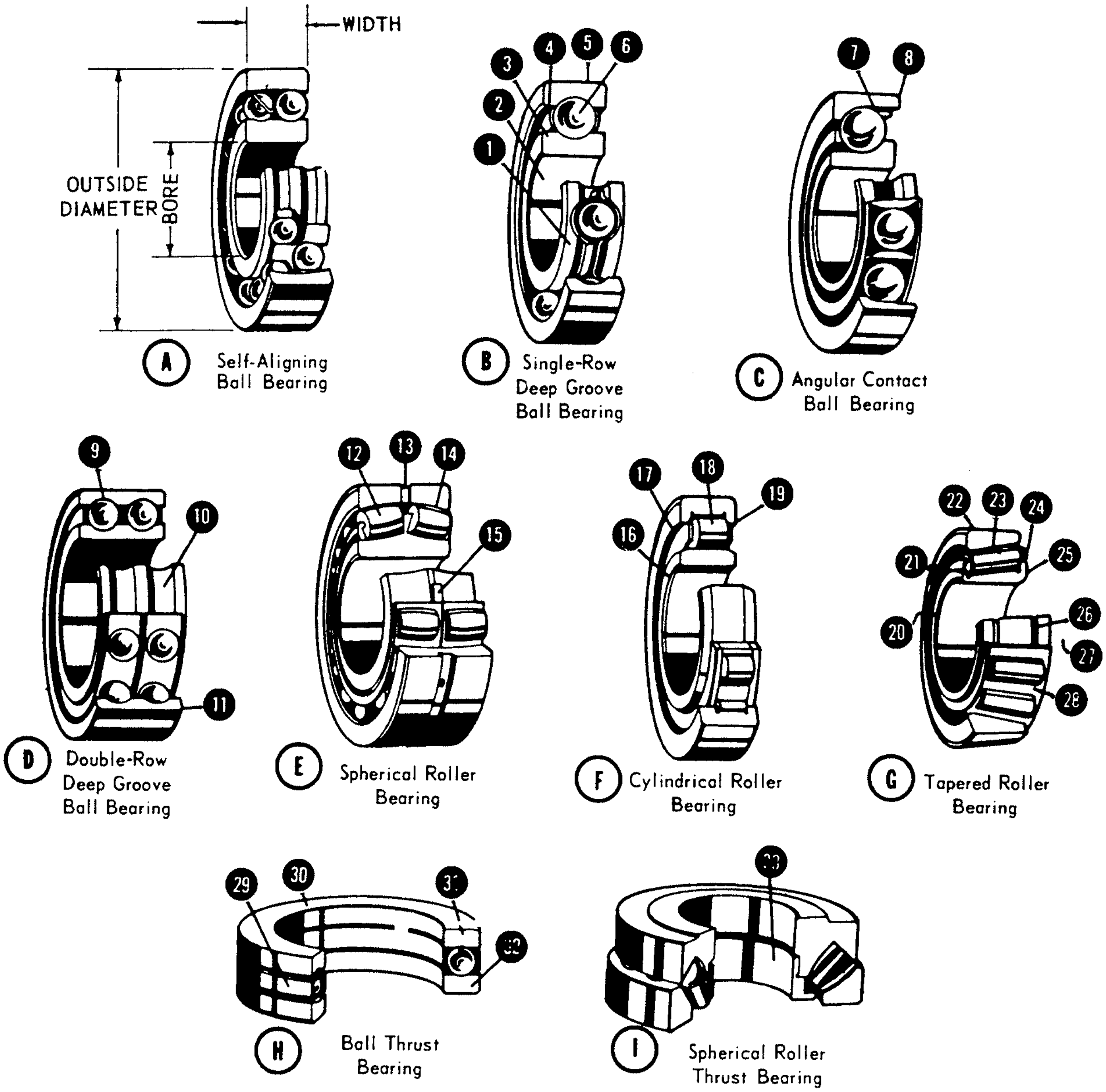
653.4 Bearings

.41 **Types.** Centrifugal pumps use many kinds and types of bearings. The most common are antifriction, sleeve, and Kingsbury.

.42 **Antifriction Bearings.** Antifriction bearings have rolling elements, either balls or cylinders, and may be single- or double-row type. Ball bearings are widely used for large shafts. Two angular-contact matched bearings mounted back to back are used on many units to carry the thrust load in either direction as well as the radial load. (See Figure 6-61 for illustrations of antifriction bearings).

.43 **Sleeve Bearings.** Two types of sleeve bearings are discussed as follows:

a. Plain Sleeve Bearings. Plain sleeve bearings usually consist of babbitt-faced sleeves placed around the shaft. In some instances, especially in vertical pumps, the bearing material may be bronze. This bearing carries radial loads only.



1. Inner Ring
2. Inner Ring Corner
3. Inner Ring Land
4. Outer Ring Land
5. Outer Ring
6. Ball
7. Counter Bore
8. Thrust Face (Face)
9. Outer Ring Raceway
10. Inner Ring Raceway
11. Outer Ring Corner
12. Spherical Roller
13. Lubrication Feature
14. Spherical Outer Ring Raceway
15. Guide Ring
16. Inner Ring Side
17. Outer Ring Side
18. Cylindrical Roller
19. Locating Rib
20. Cone Front Face
21. Cone Front Face Rib
22. Cup (Outer Ring)
23. Tapered Roller
24. Cone Back Face Rib
25. Cone Back Face
26. Under Cut
27. Cone (Inner Ring)
28. Cage
29. Ball Cage
30. Face
31. Small Bore Washer
32. Large Bore Washer
33. Sleeve

Figure 6-61

COMMON PARTS OF ANTIFRICTION BEARINGS

b. Spherically Seated Sleeve Bearings. The spherically-seated, self-aligning sleeve bearing shown in Figure 6-62 consists of a normally constructed sleeve bearing mounted in bushings having spherical contact with the bearing body. The bearing can thus assume perfect alignment with the shaft. The bearing bodies for these bearings are separate and are bolted and doweled to the lower half casing. The bushings are cast iron and babbitt-lined with no adjustment for wear. When these bearings have worn, unless the spherical seat of the bushings or body has been damaged, it is necessary only to replace both halves of the removable linings.

.44 Kingsbury Thrust Bearing. This bearing uses stationary, segmental, babbitted thrust shoes that ride on an oil film carried by a thrust collar revolving with the shaft. All of the thrust is supported by the oil film. Any failure of this film permits metallic contact, and burns out the thrust shoes. Figure 6-63 shows the Kingsbury babbitted thrust shoes supported so that they lift slightly at one end (facing the direction of collar rotation) and slide on the oil film surface. Each set of thrust shoes is held in place by a spherically-seated aligning washer, so that the shoes can adjust themselves to the thrust collar. The thrust collar is

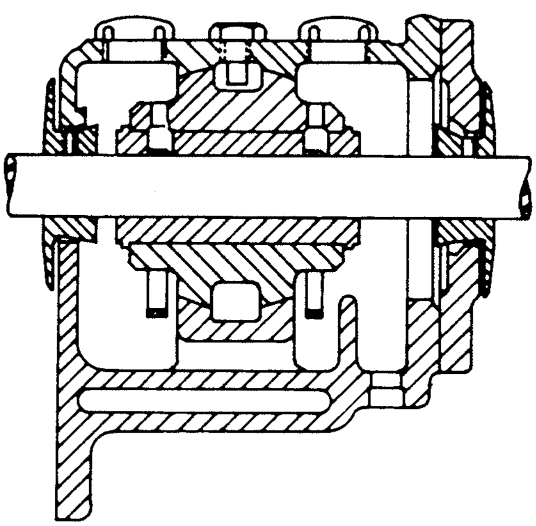


Figure 6-62

SPHERICALLY SEATED PLAIN BEARING

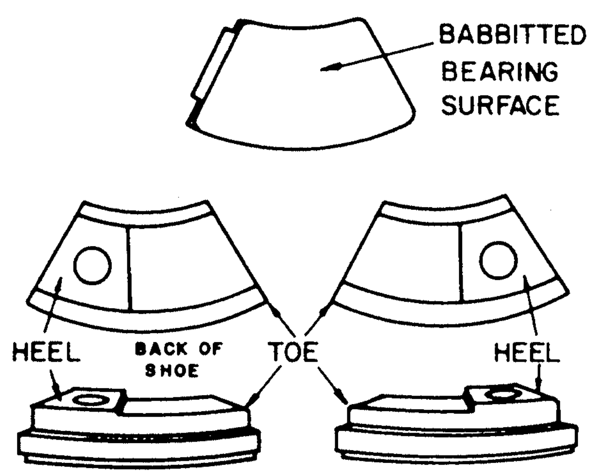


Figure 6-63

KINGSBURY THRUST SHOES

an integral part of a long sleeve that is keyed to the shaft. True collar rotation is thus ensured.

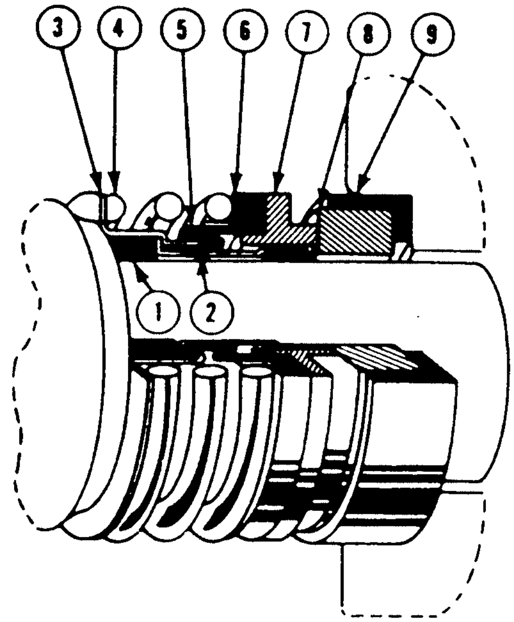
653.5 Shafts and Sleeves

Pump shafts not only transmit power from the driver to the impeller but must also withstand the radial load imposed on the impeller. Shafts are machined and ground to close tolerances at critical points. Shafts of some small pumps are stainless steel and do not require shaft sleeves. Shafts for larger pumps are made of steel and require some form of shaft sleeve to protect the shaft at critical wear points. Shaft sleeves are bronze for standard noncorrosive applications.

653.6 Shaft Seals

.61 General. The shaft seal on centrifugal pumps keeps the air out and the fluid in the pump. Two basic systems are used to accomplish this: the mechanical seal and the packing gland.

.62 Mechanical Seal. A mechanical pump seal prevents any fluid leak by having two matched, extremely flat, mated faces: one stationary and the other rotating with the pump shaft. Machining procedures of the larger pump manufacturers are such that misalignment of the seal parts is practially nonexistent. The average heating/cooling system seal uses a carbon ring rotating against a hard material, the choice of which varies with the manufacturer. The most popular materials are cast iron, ceramic, and tungsten carbide. The carbon ring always shows the greatest amount of wear, being softer than any of the hard materials. Figure 6-64 shows a mechanical seal.



Here's how the Rotary Seal assembly works. contact between surface of seal face (7) with mating stationary seal seat (8) forms a running joint. The spring (4) holds the seal face tightly against the stationary seal seat and internal gas or liquid bolsters this force. Flatness and smoothness is so exact that no gas or liquid can escape

The back of the seal face rests against the front surface of the resilient, flexible diaphragm (5), forming a leak proof joint. In turn, the flexible diaphragm is confined under radial pressure between the outer shell (3) and the inner shell (2). The inner shell has two flared driving lugs, which engage in corresponding recesses in the seal face (7) which accomplishes a positive drive between the seal parts and the seal face. A positive drive between the seal assembly and the shaft is effected by a tight compression fit between the friction ring (1), and shaft and the outer shell (3) of the seal assembly.

The seal assembly is held to a predetermined length by a shoulder on the shaft or some other part assembled to the shaft. The stationary face (8) and its accompanying gasket (9) are fitted into the stationary portion of the pump with sufficient radial interference so that the seat gasket (9) forms a positive leak-tight gasket and holds the seat from rotating

Figure 6-64

MECHANICAL SEAL INSTALLATION

653.7 Packing Glands

The stuffing box reduces the leakage around the pump shaft to a minimum. Packing rings are fitted around the pump shaft and squeezed together with the packing gland. The more pressure put on

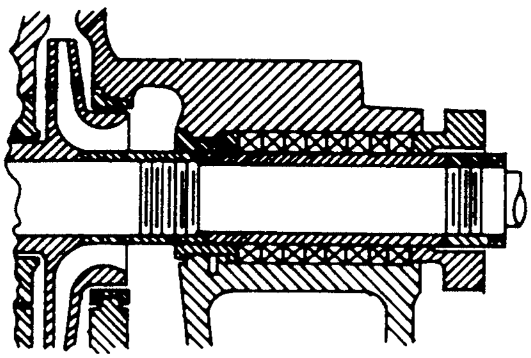


Figure 6-65
STUFFING BOX

the rings by the gland, the tighter the rings fit around the shaft, thus reducing the leakage around the shaft. This type of water seal always requires some leakage to lubricate the shaft. Figure 6-65 shows a stuffing box packed solidly, completely filled with packing. The following is a general classification of the types of packing used in centrifugal pumps:

a. Class 1. Woven or braided cotton asbestos or flax

b. Class 2. Metallic, aluminum, or babbitt

c. Class 3. Plastic

654 CENTRIFUGAL PUMP CHARACTERISTICS

654.1 Rating Curve

Any centrifugal pump has, for a particular speed and particular diameter impeller, a rating curve which indicates the relationship between the head (or pressure) developed by the pump and the flow through the pump.

654.2 Operating Curves

Figure 6-66 shows a typical manufacturer's pump operating curve. These operating curves give actual pump figures for the following:

a. Total head (in feet)

b. Capacity (in gallons per minute)

c. Required horsepower at different heads and capacities

d. Net positive suction head (npsh)

654.3 Total Head

The total head in feet shown on the vertical scale in Figure 6-66 is the amount of head (static and friction) in feet that a pump will overcome at any given capacity. It will be noted on the curves that the highest head developed is at the "0" capacity mark. This head is obtained by closing off the discharge valve on a centrifugal pump so that there is no flow through the pump.

NOTE

Do not close off the suction valve to the pump.

654.4 Capacity

The pump capacity is shown along the horizontal scale at the bottom of the chart in gallons per minute (gpm). The capacity that a pump will produce decreases with an increase in head pressure, as shown on the pump curve. The capacity increases with an increase in impeller diameter. The maximum capacity of the 5-1/2 inch impeller at 1750 rpm is 80 gpm with a 22-1/2 foot head, while the 6-3/4 inch impeller will pump 140 gpm with a head of 31 ft at the same speed.

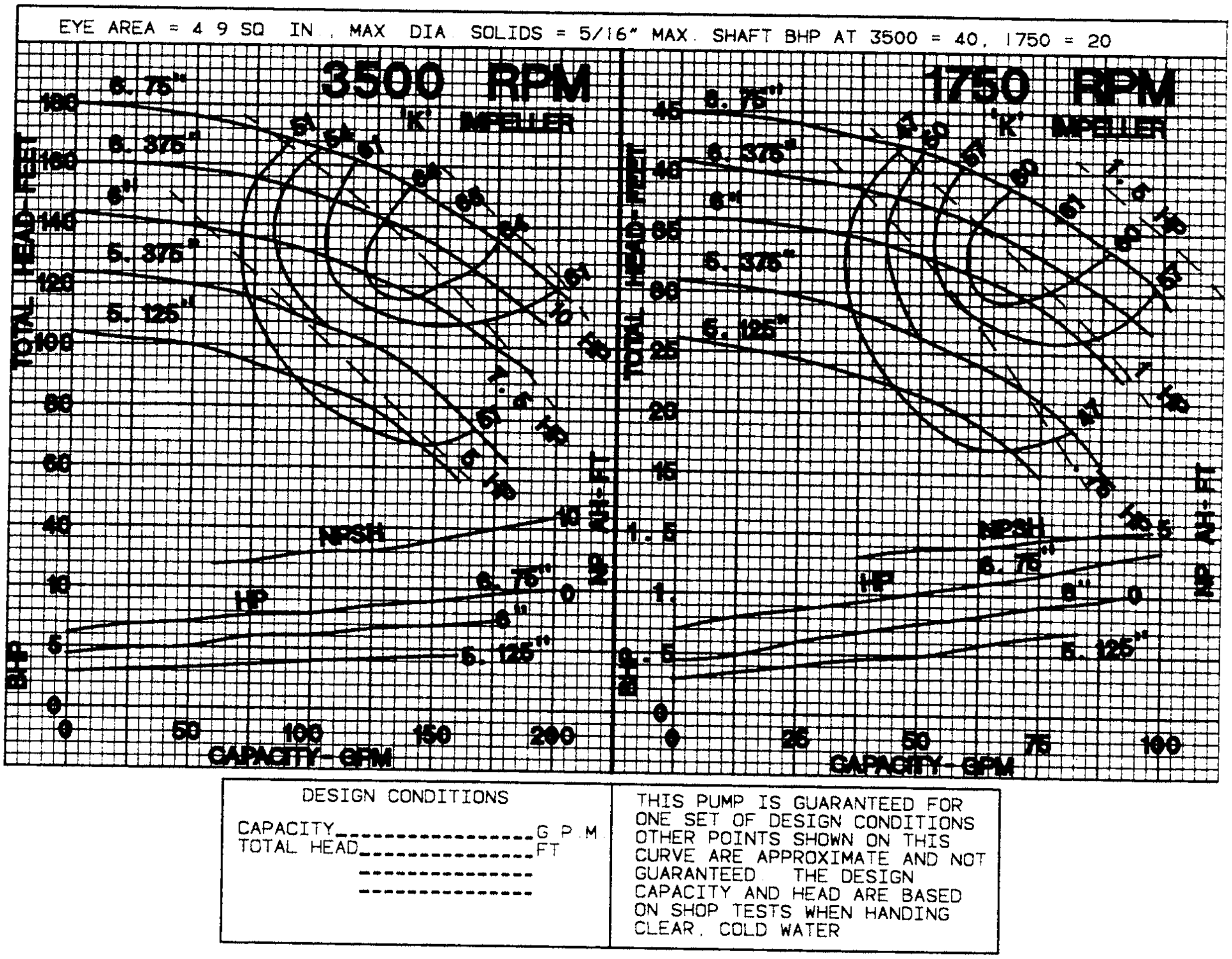


Figure 6-66

PUMP CHARACTERISTIC CURVES

654.5 Brake Horsepower

The brake horsepower (bhp) requirements are shown on the lower portion of the vertical scale. Brake horsepower is the total power required by the pump to do a specified amount of work and is equal to the hydraulic horsepower plus the friction horsepower. Brake horsepower is computed by this formula:

$$\text{bhp} = \frac{\text{capacity, in gpm X head, in feet}}{\text{3960 X pump efficiency}}$$

From this formula and the bhp curves, it is evident that the required horsepower increases with the product of the head and capacity.

654.6 Net Positive Suction Head

The net positive suction head (npsh) is the head (in feet) required at the eye of the pump impeller to prevent cavitation. This characteristic of a centrifugal pump is very important. It is always given on a pump-performance curve which is a curve showing the relationship between the capacity which the pump will deliver and the npsh required for proper operation of the pump at that capacity. A lack of the required amount of npsh measured in feet of liquid that is being pumped, causes the pump to operate at a low suction pressure that causes cavitation on a centrifugal pump. Therefore, the required amount of npsh is that amount of pressure (in feet of liquid) required for proper operation:

a. To overcome friction losses from the suction opening to the impeller vanes.

b. To create the desired velocity of flow into the vanes.

655 CAPACITY

Capacity in gallons per minute (gpm) determines pump size. When pump size is stated in inches, the reference is to the pipe or flange size of the connection. A change of speed always results in a change in capacity, head, and horsepower. If the speed of a centrifugal pump is doubled, the head developed by the pump is quadrupled, because the head developed is proportional to the square of the velocity. When the speed at which a centrifugal pump is operating is doubled, the capacity that the pump can handle is doubled. This is because the velocity through the impeller has doubled. If a pump with a given impeller diameter is capable of developing 50 foot total head at 100 gpm at 1750 rpm, then the pump will develop 200 ft total head at a capacity of 200 gpm when operating at 3500 rpm. This is shown in the formula for horsepower:

$$HP = \frac{H \times C \times \text{Specific Gravity} \times 100}{3960 \times \text{efficiency}}$$

where: H = head, in feet
C = capacity, in gpm

When the speed is doubled, the head is increased by a factor of four and the capacity by a factor of two. Assuming that the efficiency and the specific gravity remain the same, the required horsepower is increased by a factor of eight. For this reason, the speed of a centrifugal pump cannot be arbitrarily increased. A pump that was to operate at one speed is built to transmit additional horsepower if the pump is run at a higher speed.

656 MONITORING PUMP OPERATION

656.1 General

The mechanical condition of a pump can be determined by periodically monitoring its performance. The data obtained from various instrument readings is compared to the operating (performance) curves provided by the pump manufacturer and to previous instrument readings. The results of the comparison are then analyzed and a determination made, based on experience or the manufcturer's recommendation, whether or not the pump should be opened for inspection and overhaul.

656.2 Gauge Check

One measurement needed to determine the condition of the pump is the discharge pressure (or head). Pressure is measured by a gauge permanently installed in the discharge side of the pump. If possible, the gauge should be installed at the pump discharge flange. To apply the pressure data to the performance curves, pump capacity must also be determined. Capacity readings are obtained from a flowmeter, also installed on the discharge side of the pump, that measures all the water discharged by the pump.

656.3 Prime-Mover Load Check

A change in power input to the pump motor at a given capacity is an indication of trouble. The load on the motor is usually measured with an ammeter. If, for the same amount of water, more amperage is required to operate the pump than when the pump was new, the pump needs attention. It is recommended that the performance of the pumps be checked periodically. The data obtained from the checks should be plotted on graph paper, with total head and horsepower plotted against capacity in gpm. The resulting curve will show the progress of wear or other factors of deterioration in the pump. When plotting the test data, be sure to use the same capacity reading on which the new pump performance was based.

657 PUMP MAINTENANCE

657.1 Mechanical Seals

.11 Failure and Causes of Failure. Failure of mechanical seals, as applied to heating and air-conditioning, mostly occurs at the faces of the seal. If the stationary face is scored, dirt or scale is probably embedded in it. Mechanically, failure of the seal occurs when there are comparatively large fluctuations in pressure. The smooth, lapped surfaces of the seal are very sensitive to the minute distortion resulting from pressures exceeding the strength of the seal material. The resulting wear permits leakage past the seal. Failure of the seal is also caused by poor heat dissipation. Poor lubrication and the lack of ability to carry heat, caused by friction away from the seal, results in heat checking of the seal surface and the eventual destruction of the seal. Although seal failure is mostly attributed to face material wear or deterioration, it is a good idea to remove the spring assembly and inspect it for possible distortion or damage.

.12 Replacing Seals. Because of the many types of seals, no general instructions for replacing seals can be included in this handbook. However, instructions are provided by the pump manufacturer and should be followed carefully. Before disassembly, mark the position of the seal on the shaft or be sure of the dimensional setting required. It is important that seals be installed in the correct position to avoid excessive pressure on seal faces causing leakage past the seal.

657.2 Pump Gland Packing

.21 Failures and Causes. Failure of pump gland packing is indicated by excessive leakage. This type of failure is usually caused by worn packing, worn shaft sleeves, or improper tightening of the gland nuts.

.22 Replacing Packing. Replace packing as follows:

a. First remove the packing gland. With the use of a packing hook, remove all the old packing without scratching the shaft.

b. Clean the inside of the stuffing box so that the new packing can move easily inside it.

c. Make sure that the new packing is the correct type and size. If the packin is cut from a roll, cut the length slightly shorter than the inside circumference of the stuffing box when the ends are butted together. The cut ends should be square and clean with no loose strings hanging from them.

d. Roll the packing flat by tapping it lightly with a hammer for easy installation. Form into rings.

e. Insert each packing ring separately as far as possible into the box, seating it firmly. Stagger the butted ends 90° or 180° apart. Tap each new packing ring into place in the box. If a seal cage is used, be sure to locate it under the hole that supplies the seal cooling water.

f. When the required number of rings have been inserted, install the gland an tighten it by hand. Back off until the gland is loose. Turn the shaft by hand i the normal direction of rotation to leve off any high spots in the packing. Tighten the gland just enough to prevent excessive leakage before starting the pu

g. It is a good practice to start the pump with the stuffing box gland quite loose. As the packing adjusts itself to the shaft, and after the pump has been running for about 10 to 15 minutes, gradually tighten the gland until leakag is reduced to the desired number of drop per minute. Keep the gland square with the pump shaft at all times. If the glan becomes too hot to touch while the pump is operating, it is probably too tight. If it is impossible to add the last ring of packing in the box and still insert the gland, omit the ring and tighten the gland as described. Continue to tighten the gland daily, allowing for proper leakage, until the packing has seated itself enough to allow the last ring to be inserted.

657.3 Bearing Maintenance

See Handbook MS-43, General Maintenance for Mail Handling Equipment, for bearin care and maintenance.

660 PUMPING SYSTEMS

661 GENERAL

Pumping systems, as applied to heating and air-conditioning, are used to circulate and feed water, through piping and other equipment, to air-handler unit coils. They also transfer heat from the refrigerating condenser to the cooling tower. Pumping systems fall into two main categories. One system is known as the open type, such as that installed between the condenser and cooling-tower system. The other is known as the closed type, as applied to piping hot and cold water to and from the air-handling coils. It differs from the open system in that it is sealed off from the atmosphere. The open system is open to the atmosphere at the cooling tower.

662 HEATING SYSTEM PIPING ARRANGEMENTS

662.1 Types of Piping Arrangements

In the heating system, hot water is circulated by the pump to several points in the building, returned directly to the boiler and then goes back to the pump. The piping arrangement in postal facilities can be divided into three general classifications, as follows:

a. One-pipe arrangement

b. Two-pipe arrangement

c. Four-pipe arrangement

662.2 Diagrams

In large facilities where the demand for heat varies from one part of the building to another, separate pump systems are required on the same boiler using the same expansion tank. To efficiently maintain complex pumping systems, it is recommended that a drawing of the installation's piping be kept readily available. Piping diagrams are useful in determining what units are included in a given pump system. They also ensure the correct size of pipe and fittings when replacement is required.

663 COOLING SYSTEM PIPING

663.1 Chilled-Water Systems

Chilled-water pump systems are similar to the heating systems. One difference is the use of a smaller expansion tank in the chilled-water system because of the lower water temperature, which results in a reduced amount of expansion. Also, the pressure in the tank is maintained by a pressure-regulated water line feeding into the bottom of the tank. The water compresses the trapped air in the top of the tank to a predetermined pressure and is controlled by a pressure regulator.

663.2 Condenser-Water Systems

A typical condenser-water pump system is illustrated in Figure 6-67. It is a single-pipe, open-pumping system, because the circuit is broken at the cooling tower. The suction head on the pump depends on the vertical distance from the pump inlet to the free water surface in the tower sump. The column of water standing in the pipe between the pump and the tower sump is the only way of pressurizing this system to provide the pump with positive pump suction. The condenser and the height to which the water must be pumped provides the only resistance to flow and the ability of the pump to produce the necessary flow. The size of the piping is such that it offers negligible resistance.

664 SYSTEM HEAD

664.1 General

The system head is the algebraic sum of the static head on the pump discharge, minus the static head on the pump suction, plus the friction losses through the entire system of fluid flow. The relationship between head (in feet of liquid) and pressure measured in psi is shown in the following equation:

$$H = 2.3p$$

where: H = head, in feet
p = pressure, in psi

Pressure caused by resistance of the piping, pipe fittings, and actual lift of the water, added to the pressure required to force the water through the coils, equals the Total Dynamic Head.

664.2 Static-Pressure Head

Static-pressure head is the height to which the water can be raised by a given pressure. In other words, it is the weight of the entire column of water that the pump normally pumps against converted to feet of water head.

664.3 Friction Head

In any pipe through which a fluid is flowing, there is a loss of pressure. The loss of pressure (or friction head) depends on the velocity of the water, the pipe diameter and length, and the degree of roughness of the inside pipe surface.

664.4 Suction Head

Suction head is the pressure measured at the suction port of the pump. When the source of supply is below the pump, the condition is known as static suction lift. When the source of supply is above the pump, it is known as static suction head. One characteristic of a pump is that a certain amount of energy is needed to fill a pump on the suction side and overcome the friction and flow losses from the suction connection to that point in the pump at which more energy is added, such as the pump shaft. The amount of energy in the water at the pump inlet is known as the net positive suction head (npsh). In a centrifugal pump, the required npsh is that pressure, in feet of water, required to

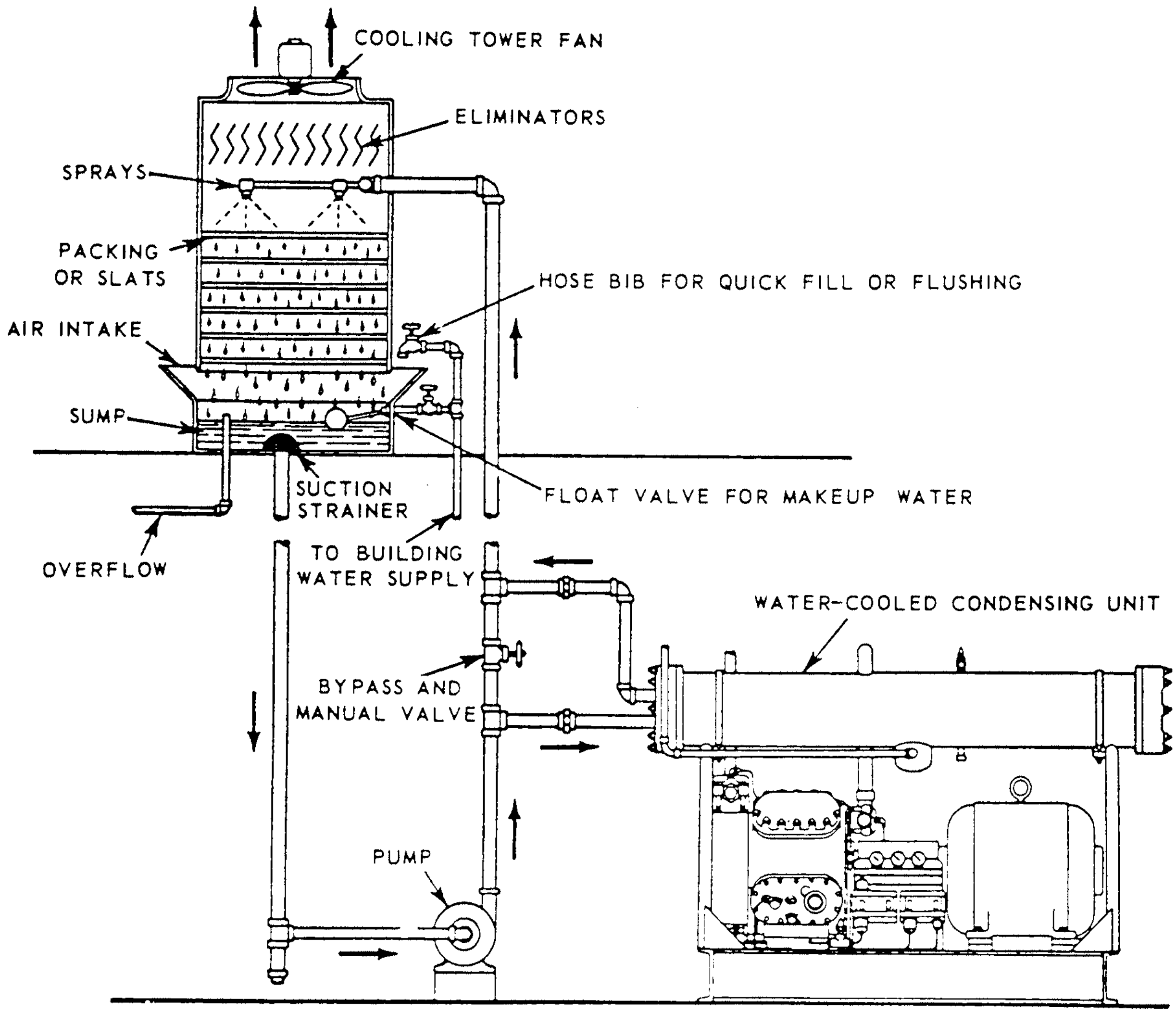


Figure 6-67

TYPICAL COOLING-TOWER SYSTEM

overcome friction losses between the suction opening and the impeller vanes and to create the desired velocity of flow into the vanes.

665 SYSTEM CHECKS

665.1 General

To detect existing or pending failures in a pump system, periodic checks should be made. First, it must be assumed that the system has been balanced. Balancing of the system consists of properly metering the flow through each coil so that it gets its share of the total amount of flow. Once the system is in balance and the amount of flow in each coil and total flow is charted, any deviation from the normal should be followed by a check to determine the reason for the change.

665.2 Gauges

System checks are made by measuring pressures and flow throughout the system. This is done through the use of pressure gauges strategically installed in the system. Gauges are normally installed on both the suction and discharge side of the pump. Because of variations in pressure and flow that exist in the system due to branch circuit demands, the net positive suction head (npsh) will be affected. A lack of the required amount of npsh, measured in feet of water, will cause the pump to operate improperly. This data is obtained from the suction side pressure gauge. The reason the gauge is installed on the discharge side of the pump has been discussed in Section 656.2. Other pressure gauges are installed, some permanently and others temporarily, at each of the coils. They are installed one on each side of an orifice flange and used to measure the pressure drop across the orifice. This data, by graph or calculation, is converted to quantity of water flowing through that particular leg of the system.

665.3 Pump Curves

The data obtained from pressure gauge readings are applied to the pump-performance curves as described in Section 654.2. Any deviation from the standards, as established by the curves for a given capacity and total head, is cause for further inspection of the system. A troubleshooting guide, Table 6-4, has been provided to aid in identifying some of the causes of abnormal operation.

665.4 Pressure Levels

All centrifugal pumps have a rating curve, as stated in Section 654.1, that indicates the relationship between the head (or pressure) developed by the pump and the flow through the pump. The rating curves establish the pressure limitations within which the pump will operate satisfactorily. By consulting the net positive suction head curve, the minimum suction pressure can be determined. The head-capacity curve determines the best discharge pressure for a particular required rate of flow.

665.5 System Inhibitors

.51 Algae and Slime. Algae consists of tiny plant cells that multiply and produce large masses of plant material in a short time. Slime growth consist of a gelatinous mass that clings to practically all surfaces in the condenser system, trapping organic matter, debris, and scale-forming material. When the microbiological growths break loose from the tower, they clog lines, pumps, and heat exchangers. The key to combating algae and slime is mechanical cleaning followed by chemical treatment. Good housekeeping requires the periodic cleaning of the condenser-pump system to remove mud, silt, leaves, twigs, algae, slime, etc., that may have collected.

.52 Scale. The evaporative process used to cool water in the condensing-water circulating system results in the concentration of dissolved solids in the water. Scale-forming salts are produced and deposited on surfaces in contact with the water. Deposits of calcium carbonate from the condensing water are normally the chief scale problem, although deposits of calcium silicate, magnesium silicate, and calcium sulphate may also be encountered. Since the solubility of calcium carbonate decreases as the temperature increases, the deposits usually show up first in the hottest part of the system, the tubes of the condenser. A buildup of scale in the condenser lowers the rate of heat transfer, reduces the efficiency of the refrigeration machine, results in an increase in consumption of electricity, and may cause the refrigeration machine to cut out because of high head pressure. In some water (such as that fairly low in hardness) the deposit of scale can be minimized by adequate bleed at the tower. In cooling towers, bleed, along with chemical treatment, is required.

.53 **Corrosion.** Corrosion is generally the result of dissolved oxygen and acid gases in the water. The chief offenders among the acid gases are carbon dioxide and sulphur dioxide picked up from the atmosphere. The means and effect of cleaning water in a pumping system are described in Chapter 4.

666 GENERAL STARTUP AND FOLLOWUP

After it is determined that a pump is in good condition, certain steps must be taken before it is placed in operation. Many pumps require steps unnecessary in other pumps. For example, for radial-type impellers, the discharge valve should be closed at startup. For the mixed-flow or propeller-type pumps, the valve should be fully open and the following steps taken:

a. Check that the bearings are filled with lubricant according to the manufacturer's recommendations.

b. With the coupling disconnected, test for correct direction of rotation and freedom of rotation.

c. Turn on the cooling-water system for the pump bearings, stuffing boxes, and mechanical seals, if these parts are liquid cooled or lubricated.

d. Prime the pump (follow the manufacturer's recommendations).

e. Close or open the discharge gate valve, depending on the starting procedure.

f. If the pump should not be started against a dead shutoff, open the recirculating valve.

g. Start the motor and allow the pump to come up to speed.

h. Open the discharge valve slowly.

i. Check the leakage from the stuffing boxes. Adjust the sealing-liquid valve for proper flow to ensure the lubrication of the packing. If the packing is new, do not tighten up on the gland immediately. Let the packing run in before reducing the leakage through the stuffing boxes.

j. Check the general mechanical operation of the pumps and motor.

k. Close the recirculating valve once there is sufficient flow through the pum to prevent overheating.

l. Check the pump suction, discharge, lube-oil, cooling-water, and sealing-water pressures and temperatures against the manufacturer's specifications.

m. Check the electric motor amperage to ensure that the motor is not overloaded.

NOTE

If the pump is started with the discharge valve open, the steps are the same, except that the discharge valve is opened sometime before the motor is started.

667 RECORDING PUMP DATA

While the pump is running, periodic checks should be made on suction and discharge pressure, stuffing box leakage, and bearing temperatures. No record is necessary for these readings, but the operator should report any discrepancy in pump operation. It is recommended that maintenance cards be kept on each pump. The cards should identify the pump, the date maintenance was performed, and the condition of the parts to be repaired or replaced. This data, plus the operating hours, help to make future decisions as to whether it is more economical to repair or replace the entire pump.

668 PREVENTIVE MAINTENANCE

A sample preventive maintenance checklist for various types of pumps is shown in Exhibit 6-4, Appendix C.

669 TROUBLESHOOTING GUIDE

Table 6-4, Troubleshooting Guide, lists the most common troubles occurring in centrifugal-type pumps. It includes the probable causes and recommended remedies for correction. Data in this guide is of a general nature and is intended to provide a standard approach to identifying and analyzing the most common troubles. It is recommended that this guide be reviewed at the local level and expanded, if necessary, to include the results of local experience.

NOTE

While performing troubleshooting procedures, observe all normal precautions for safeguarding personnel and equipment.

TABLE 6-4

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE PUMPS

COMPLAINT	CAUSE	POSSIBLE REMEDY
1. No water is being delivered.	a. Pump not primed	a. Refer to text paragraph on Startup.
	b. Speed too low	b. Check whether motor is directly across the line and receiving full voltage. In case of steam turbine, check governor and determine if receiving full steam pressure.
	c. Discharge head too high	c. Check operating conditions. See that pipe friction and suction and discharge heads are as specified.
	d. Suction lift too high	d. Check with gauges. Normal suction should not exceed 15 feet.
	e. Impeller and/or piping plugged	e. Inspect piping, suction strainer, and impeller.
	f. Impeller rotating in wrong direction	f. Check shaft rotation against pump case direction arrows or manufacturer's literature
2. Not enough water is being delivered.	a. Air leaks in suction line or stuffing box	a. Plug inlet and pressurize. A gauge in line will indicate leakage with a drop in pressure. A 1 percent leak may cause the capacity to decrease 10 percent.
	b. Speed low	b. Refer to text paragraph on starting.
	c. Discharge head higher than anticipated	c. Check operating conditions. See that pipe friction and suction and discharge heads are as specified.
	d. Suction lift too high	d. Check with gauges. Normal suction should not exceed 15 feet.
	e. Impeller or suction line partially plugged	e. Inspect piping, suction strainer, and impeller.
	f. Not sufficient suction head for hot liquid	f. Hot liquids in almost all cases must flow by gravity and have sufficient head or submergence to eye of impeller. Refer to pump manufacturer for complete information on suction piping, size and type of liquid, and amount of submergence available.
	g. Wearing rings worn	g. Refer to text paragraph on bearings.
	h. Impeller damaged	h. Repair or replace.
	i. Foot valve too small	i. Inspect. Net area should be at least equal to area of pump suction but preferably larger. Suction-strainer area should be at least three or four times the area of suction pipe.
	j. Casing packing defective	j. Replace all worn packing.
	k. Foot valve or suction opening not submerged enough	k. Submerge entrance of suction pipe at least three feet below surface of the liquid.

TABLE 6-4 (Continued)

TROUBLESHOOTING GUIDE FOR CENTRIFUGAL-TYPE PUMPS

COMPLAINT	CAUSE	POSSIBLE REMEDY
3. There is not enough pressure.	a. Speed too low	a. Check whether motor is directly across the line and receiving full voltage. In case of steam turbine, check governor and determine if receiving full steam pressure.
	b. Air in the water	b. Plug inlet and put line under pressure. A gauge in line will indicate leakage with a drop in pressure. A 1 percent air leak may cause the capacity to decrease 10 percent.
	c. Wearing rings worn	c. Refer to text paragraph on bearings.
	d. Impeller damaged	d. Repair or replace.
	e. Casing packing defective	e. Replace all worn packing.
4. Pump works for a while and then loses suction.	a. Leak in the suction line	a. Plug inlet and put line under pressure. A gauge in line will indicate leakage with a drop in pressure. A 1 percent air leak may cause the capacity to decrease 10 percent. (An 8 to 10 percent air leak will cause pump to lose its prime.)
	b. Water seal plugged	b. Inspect line and position of seal cage in stuffing box.
	c. Suction lift exceeds 15 feet.	c. Check for obstruction in suction line and for low water level.
	d. Air or gas found in the liquid	d. Vent suction back to source of supply.
5. Pump takes too much power.	a. Speed too high	a. Check speed of driver or, in case of belt drive, sheave or pulley diameters.
	b. Mechanical defects, such as a bent shaft	b. Check runout of shaft. Total runout allowed depends upon pump design and speed. Approximately 0.003 inch for high-speed and 0.006 inch for low-speed units.
	c. Rotating elements binding	c. Check for too tight stuffing boxes, wearing-ring fit, and defective packing.

CHAPTER 7

SERVICE CONTRACTS

710 AUTHORITY

This handbook does not delegate contracting authority. See the Administrative Support Mannual (ASM), Pub. 41, Postal Contracting Manual for contracting authority.

720 REFRIGERATION SERVICE

A refrigeration-service contract is permissible for those installations where maintenance personnel are not qualified to perform the routine preventive maintenance. Usually, buildings requiring 60 tons of refrigeration and over have maintenance personnel qualified to operate and maintain the equipment properly without a contract. A refrigeration contract should not be needed at buildings requiring less than 60 tons of refrigeration, if a member of the maintenance staff has satisfactorily completed a course at a USPS basic air-conditioning maintenance school. A sample to be used for obtaining this service is shown as Specification 7-1.

730 WATER-TREATMENT

Service contracts for water-treatment may be obtained from qualified water-treatment concerns, if maintenance personnel are not qualified to perform the necessary water-treatment prescribed in Chapter 4, or if the prescribed program has been followed and has proven ineffective. A sample to be used for obtaining this service is shown as Specification 7-2.

740 CONTROLS

Note that the specifications for a refrigeration-service contract include controls only for self-contained HVAC as defined in Chapter 2. For central systems, as defined in Chapter 3, a separate service contract is required for the controls. The need could be due to a malfunction of a particular control which would involve only the services of an electrician, or possibly calling in a representative of the manufacturer for corrective action, depending on the nature of the trouble and whether the guarantee period had expired. If the trouble involves a gradual increase in the number of malfunctions after an installation has been operating several years following the guarantee period (indicating the need for a general overhaul and adjustment of the system), then a contract should be executed using the specifications specially prepared for the type of contract required. A sample for obtaining this service is shown as Specification 7-3.

750 EDDY-CURRENT TESTING

Initial eddy-current testing is required on central refrigeration equipment which has been in service for 10 years where dual chillers are installed and 5 years where a single chiller is installed. Retesting is then required every 5 years after the initial test. This testing is beyond the capabilities of USPS personnel.

760 TECHNICAL ASSISTANCE

If technical assistance is needed regarding service or maintenance requirements, contact the district Buildings Management Engineering Office (BMEO). If assistance in procurement and contracting is needed, contact the district manager.

SPECIFICATION 7-1

REFRIGERATION SERVICE

I. **MONTHS COVERED** The months covered under this specification shall be ____. Quotations shall be submitted covering these months. A quotation for each month is desired, preferably in equal amounts.

II. **REFRIGERATION** The following items apply to both self-contained units and central systems. Note that temperature control (or control system) is covered separately under Item III.

A. Start of Cooling Season. At the start of the cooling season (see Item I above)the following services shall be performed by a qualified refrigeration and air-conditioning maintenance contractor:

1. General. Visually and manually check the component parts of the refrigeration cycle and the system to determine that all valves and mechanical operators are correctly positioned for the system's mechanical operation.

2. Compressor Oil. Check compressor oil level.

3. Refrigerant. Check refrigerant level.

4. Cooling Tower. Check cooling tower and fill condensing system. Check if bleed line is tapped into the condensing water line between the pump and thetower so that water is bled to waste only when the tower is operating. Vacuum clean or wash condenser coils and fins of units using air-cooled condensers.

5. Expansion Tank. Check expansion tank, if provided, for chilled-water level.In the case of direct expansion coils, vacuum clean or wash condenser coils and fins.

6. Operating Check. Place system in operation and, for the first 30 minutes, continually check oil level and refrigerant level. Add oil and refrigerant ONLY after oil or refrigerant leaks have been found and repaired.

7. Inspection. Perform inspections as called for under Item B.

B. Monthly Inspections. During each of the months set forth in Item I above, there shall be performed an inspection covering the following:

1. General. Check performance of refrigerating cycle and cooling system.

2. Operating Indicators. Check operating pressures and temperatures of the refrigeration cycle and cooling system.

3. Refrigeration Controls. Check operation of refrigeration controls and reduction devices. Check superheat setting of metering devices. (Inlet and outlet of evaporator)

4. Safety Controls. Check and adjust all safety controls.

5. Refrigerant Leaks. Inspect equipment for refrigerant leaks, using accepted leak detector. Electronic leak detector must be used on units exposed to wind. If leaks noted, provide information as to extent and repairs necessary.

6. Air Purge. Purge air from system.

7. Lubrication. Lubricate all moving parts as required by manufacturer.

8. Belts. Check and adjust tension and alignment of all belts.

9. Pump Packing. Check pump packing and adjust where necessary.

10. Strainers. Clean all strainers.

11. Valves. Inspection all valves and adjust where necessary.

12. Water Leaks. Check for water leaks.

13. Cooling Tower Water Level. Check level of water in cooling tower sump and adjust float valve if necessary.

14. Bleed. Check condensing water bleed, usually located at cooling tower or in the condensing water line between the pump and the tower. (Do not confuse with tower overflow line.) Check for proper bleed as originally set up in instructions furnished to the Postmaster. If bleed rate has not been set up properly, note on report the amount of bleed and correction made together with recommendations.

15. Air Dampers. Check and adjust air dampers for proper air distribution.

16. Miscellaneous. Make all other necessary adjustments, lubrication, preventive maintenance, etc., required for proper care of the system.

17. Check on Compressor Oil. Make final check of compressor oil and replenish if necessary.

18. Operating Procedures. Based on the findings revealed by the initial startup and inspection, review operating procedures and provide necessary written instructions for post office maintenance personnel.

C. Inspection Reports. Upon completion of each monthly inspection, the contractor shall prepare a report in triplicate for the Postmaster covering the following:

1. General. Show date of inspection and post office official or repesentative contacted. Comment should be made as to the general condition and cleanliness of the entire system.

2. Rusting. Note any rusting and need for touchup painting.

3. Filters. Note condition of filters.

4. Maintenance Personnel. Do maintenance personnel fully understand the proper operation of the equipment and the routine maintenance required?

5. Operating Indicators.

   a. Time of day observed: ______________________________

   b. Dry-Bulb Temperature: Outside _____ °F Inside _____ °F

   c. Wet-Bulb Temperature: Outside _____ °F Inside _____ °F

   d. Compressor: Head Press. ____________ lbs. _________ ozs.

      Suction Press. _________ lbs. _________ ozs.

   e. Chilled-Water Temperature: In ______ °F Out ______ °F

   f. Direct Expansion Systems: Return air temp. __________ °F

   g. Discharge Temperature at coil: _________ °F

6. Services Performed. List services performed.

7. Instructions. List comments or instructions given to the post office officials or maintenance personnel and mention the men by name and title. State if previous instructions given have been followed and if the results have been satisfactory.

8. Repairs. List any repair work, replacement of wornout parts, etc., if required, and approximate cost.

D. End of Cooling Season. At the end of the cooling season as indicated under Item I, the following shall be performed:

1. Refrigerant Charge. Pump down and store refrigerant charge, if necessary. Close king valve or liquid-line shutoff valve.

2. Water. Drain water from all parts of the system likely to freeze.

3. Condenser and Cooling Tower. Inspect, clean, and flush condenser and cooling tower.

4. Compressor. Place compressor on pump-down cycle to prevent metal seizing and drying out of shaft seal.

5. Safety. Prepare a Form 1767, Report of Hazard, Unsafe Condition or Practice for each operating component of the system, indicating what was done, and attach it to the control switch or valve of each component.

III. TEMPERATURE CONTROLS

A. Self-Contained Units. Check and adjust entire temperature control system in line with the following:

1. Inside Space Thermostat(s). Adjust to maintain 78 °F in all cooled spaces.

2. Outside Air Thermostat(s). Adjust high limit outside air thermostat for 75 °F setting.

3. Outside Air Damper(s). Adjust outside air damper(s) for the minimum setting required to allow the proper amount of outside air in conjunction with maintaining space temperatures of 78 °F.

B. Central Systems. The checking and adjustment of the temperature control system for this type intallation is not the responsibility of the contractor under the terms of this specification. Arrangements for any such work, when found necessary, must be through a separate contract.

IV. BID PRICE

The bid shall show the monthly charge for the inspections covered under this bid.

V. EMERGENCY SERVICE

Emergency service shall be available between inspections under this contract. Payment for service caused by improper operation of the system or breakdowns, due to failure to follow written recommendations in a previous report, shall be at current established hourly rates.

VI. **PARTS REPLACEMENT** If inspection reveals that parts are required, new equipment shall be charged for at published list prices less applicable discount. Repair or exchange parts shall be at published prices. Wherever possible, parts shall be of the same manufacturer as those replaced. Such repair or replacement of parts must be authorized by the contracting officer or his authorized representative.

VII. **COST BASIS** In addition to the bid price, the bid shall show the hourly rate(s) to be charged for service performed under Items V and VI. The charge for the work performed under these items shall be based only on actual service performed and shall be computed on a time and fixed hourly rate basis. This hourly rate basis is to be set forth in the bid. Failure to set forth the fixed hourly rate(s) for this service shall be cause for rejection of a bid. Percent discount on list prices shall also be stated.

VIII. **QUALIFIED PERSONNEL** All inspections and authorized repair work, etc., shall be performed only by qualified personnel.

IX. **BUILDING CONDITIONS** Bidders are urged to visit the site to inform themselves as to all existing conditions. Failure to do so will in no way relieve the contractor of any performance required by this specification.

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SPECIFICATION 7-2

WATER TREATMENT OF AIR-CONDITIONING SYSTEMS

I. GENERAL

A. The contractor shall provide and install equipment, chemicals, and services required to control corrosion, scale, algae, and slime in the following systems as appropriate:

1. Cooling tower
2. Evaporative condenser
3. Chill water
4. Boilers

Contractors must furnish equipment and chemicals to the building prior to starting date of contract.

B. Automatic feeding devices shall be furnished and installed at each location by the contractor and shall remain the property of the contractor except as noted. The nature of the automatic feeding devices shall be such that no more than two Government man-hours per week shall be required in checking and/or loading the device. An amount shall be stated in the contract specifying the price of automatic feeding equipment if purchase by the USPS is desired. At the expiration or termination of the contract, all such devices, which were installed by the contractor, shall be removed at the contractor's expense and the system restored to its original condition except when the USPS desires to purchase the equipment at the price stated in the contract. Electrical outlets and current to operate the devices shall be provided by the Government at no cost to the contractor. Any installed water meters in makeup water lines are to remain property of the Government. Bypass feeders and/or pot feeders shall be used in closed loop systems and will remain or become property of the Government. The contractor shall furnish and install pot or bypass feeders when no such feeders are presently installed and usable.

C. The contractor shall have been regularly engaged in the water treatment field in the areas to be serviced for a minimum period of two years. The contractor shall submit for approval, prior to award of contract, satisfactory references, proof of competency, and detailed descriptive literature of system proposed. The treatment supplied by the contractor shall be one that has been especially designed and tailor-made for the water being used in each system. Each package of chemicals used shall be labeled, with directions for using same.

D. Contractor shall warrant that the chemicals used in the water treatment program will not endanger the health or safety of persons coming into contact with the materials and will not damage personal or real property as long as the contractor's instructions are followed. Contractor also warrants that the chemicals used in the water treatment program shall have no detrimental effect on the metallic or nonmetallic materials in the equipment being treated, and that the contractor shall maintain those conditions least conducive to delignification of the wood in cooling towers.

E. All chemicals, acids, etc., proposed for use in treatment of the specified systems will be listed in the proposal with the delivered price per pound and an estimate of the yearly amount required. When determining award of a contract, the following items will be considered: yearly cost; concentration levels; type of treatment; treatment levels; method of treating and method of control. The cost of purchasing installed equipment could also be used in determining award.

II. **SCALE AND CORROSION CONTROL**

A. The treatment program shall consist of the controlled use of scale and corrosion prevention materials as herein noted. The use of essentially toxic and staining corrosion inhibitors such as chromate will not be permitted. Corrosion inhibitors selected shall have been proven effective by at least one year's usage by the water treatment contractor. Polyphosphates are not considered as effective corrosion inhibitors. The use of inhibitors such as the organic phosphorous type will be permitted.

B. The use of either pH adjustment or chelating-type scale prevention treatments will be permitted. Where the use of acid is required for the adjustment of pH, the acid shall be a dry type when used in systems under 200 tons. Sulphuric acid may be used in other systems when pumped directly from the carboy into the system.

C. The necessary pumps, timers, controllers, etc. are to be furnished by the contractor. Electrical connections and the power supply will be furnished by the Government.

D. The contractor shall provide a completely automatic proportional pump feed and bleed system for systems over 100 tons capacity. A proportional manual feed system or a proportional pump feed system as recommended by the contractor may be used for systems under 100 tons capacity. The system shall use an automatic device to activate the chemical feed and bleed-off. Concentrations of open system water will be maintained as high as possible without reducing treatment effectiveness to conserve the use of makeup water and chemicals.

E. The control device shall provide 100 percent direct proportioning of chemical treatment to makeup water and bleed-off shall be in direct proportion to equipment load indicated by the makeup water. Control shall be by means of a solid state conductivity meter and a flow-through probe sensor. The controller is to be programmed to bleed off the system and regulate a preset solution feed pump. The water treatment must constantly prevent the buildup of adherent mineral deposits on the heat transfer surfaces of the equipment being treated. Periodic circulation of inhibited acids will not be considered as meeting these specifications.

F. When condensing temperatures, operating pressures, or other operating data indicate that the scale control program is not adequate, contractor shall provide the necessary chemicals and labor to clean the equipment immediately, and thereafter modify his program to maintain condensing temperatures, operating pressures, and other factors within the limits specified by the manufacturer of the equipment.

III. ALGAE AND SLIME CONTROL

A. Algae and slime growths shall be prevented in all water circuits by using suitable algaecides and slimicides.

B. Chemicals may be fed into water circuits requiring continuous makeup by automatic proportional feeding devices or by adding directly to the tower sump as required.

IV. SERVICE PROVISIONS

A. Contractor shall submit Form 4998 report to the Postmaster on the initial water analysis and the prescribed water treatment program. Contractor shall also submit supplemental reports subsequent to any changes required in the initial prescribed water-treatment program. Copies of all reports shall also be furnished to the head maintenance man at the facility.

B. Contractor shall make service calls and water analyses at intervals of not less than once each 4 weeks at the facility site and more often at startup of equipment. Contractor shall submit a Form 4998 for each service call and a detailed water analysis (including Langelier Index) for condenser water, to the Postmaster.

C. Contractor shall make the initial application of each material and shall furnish specific oral and written instructions to the operating personnel for the maintenance and control of the water treatment program.

D. The operating personnel may obtain samples and/or other pertinent data for the contractor, provided: The contractor furnishes written instructions, the necessary sampling containers, etc.

E. The contractor shall furnish the testing equipment and solutions for the use of the operating personnel for whatever testing may be required between visits by the contractor.

F. The contractor shall furnish and install a coupon type test samples in the appropriate water line locations. On an annual basis, these samples shall be removed and sent for analysis to determine the effectiveness of the water-treatment program in preventing deterioration of metals contained in the water system.

SPECIFICATION 7-3

AUTOMATIC TEMPERATURE CONTROL SERVICE

I. **INSPECTION AND REPAIR** One inspection is to be made during the month of ______________, 19____, and shall be performed during normal working hours which are defined as 7:30 a.m. to 4:00 p.m., Monday through Friday inclusive, except holidays. Inspection shall consist of checking the entire control system for proper working condition as designed and installed, and providing preventive maintenance which shall include the following:

A. Systematically examine, adjust, calibrate, and clean all thermostats, humidity controls, temperature controls, pressure controls, valves, relays, motors, and accessories directly pertaining to the control system(s).

B. Systematically furnish lubricants and lubricate such components as air compressors (when provided), valve packing glands, damper bearings, linkages, motors and switches directly pertaining to the control system(s).

C. The items covered under (A) and (B) refer to the basic components of the control system and it is understood and agreed that any items not mentioned but are an integral part of the control system(s) are included under this inspection contract.

II. **POST OFFICE PERSONNEL TRAINING** In the performance of this contract, the contractor agrees to accept Post Office personnel, not to exceed two persons, for the purpose of training and familiarization during this inspection.

III. **REPLACEMENT PARTS** Parts or replacement of control components shall be of the same manufacturer as those replaced; therefore, costs are not included in the maximum quotation. If inspection reveals that parts or components are required, new equipment shall be charged for at published list prices, less a stated discount set forth in the bid by the bidder. Repair or exchange parts shall be at published prices. However, such repair or replacement of parts must be authorized by the contracting officer or his authorized representative.

IV. **EXISTING CONDITIONS** Bidders are urged to visit the site to inform themselves as to all existing conditions. Failure to do so will in no way relieve the contractor of any peformance required by these specifications.

V. **ACCESS** It is understood that reasonable means of access to the equipment to be inspected will be provided by the U.S. Service (USPS).

VI. **MODIFICATIONS** Modifications to the existing control system(s) are not a part of this specification.

VII. **LIABILITY** The USPS shall not be liable for and company agrees to indemnify and hold the USPS harmless in respect to injuries or dangers to persons or property that may arise through the performance and intent of this inspection, whether direct or consequential.

VIII **COMPETENCY** Service under this contract shall be performed only by properly qualified personnel. Further, bidders shall demonstrate their competency to perform the desired work and submit with their proposal a list of comparable installations within __________ miles of __________ at which they have performed service of this nature on temperature control equipment similar to that at this Post Office building within the last five years.

IX. **COST REPAIRS** The charge for this inspection (including personnel training) shall be based only on actual service performed and will be computed on a time and fixed hourly rate basis. Bidder must quote a maximum price for this inspection (including personnel training) exclusive of parts cost. This maximum price must be stated in the bid, and any bid failing to do so will be rejected.

X. **BILLING** Upon completion of the work under this contract, the contractor shall submit to the contracting officer a certificate of the work performed and an itemized statement of costs, based on the hours worked and the hourly rate. An itemized statement of costs covering the replacement of parts must be submitted as a separate invoice.

XI. **SERVICE PERIOD** For a period of 30 days, following the completion of the inspection, emergency service shall be provided, for which no additional charge shall be made except the charges provided for in the following instances:

A. Improper Operation. A charge at the fixed hourly rate set forth by the bidder in the bid, for travel time (where applicable) and labor for any emergency service required because of improper operation of the system by the U.S. Postal Service or because of failure of the U.S. Postal Service to follow the contractor's written recommendations based on the results of the inspection.

B. Broken or Damaged Parts. A charge at the fixed hourly rate for labor used in repairing or replacing any broken or damaged parts; provided, however, that such repair or replacement of parts must be authorized by the contracting officer or his authorized representative. The charge for new equipment furnished by the contractor shall be charged at published list prices, less a stated discount set forth in the bid, and the charge for repair or exchange parts furnished by the contractor shall be actual cost.

C. Fixed Hourly Rate. Bids failing to set forth a fixed hourly rate(s) for service under this part of the specifications, will be rejected. No separate charge will be paid for travel time.

GLOSSARY

absolute humidity. Amount of moisture in the air, indicated in grains per cubic foot.

absolute pressure. Gauge pressure plus atmospheric pressure.

absolute temperature. Temperature measured above absolute zero.

absolute zero. Temperature at which all molecular motion ceases (-460 °F or -273 °C).

absorbent. Substance which has the ability to take up or absorb a liquid or gas and changes physically and/or chemically in the process.

accumulator. Storage tank or pressure vessel which receives liquid refrigerant from the evaporator and prevents it from flowing into the suction line.

acid condition in system. Condition in which refrigerant or oil in system is mixed with fluids which are acid in nature; a low pH condition in a circulating water system.

acid cleaning. A process of cleaning internal parts of steam generating units, or refrigeration condensers by filling with, and circulating, diluted acid accompanied by an inhibitor to prevent corrosion.

acidity. Represents an amount of free mineral acids and salts (especially sulfates of iron and aluminum) which cause hydrolysis and give up hydrogen ions in water and is reported as milliliters per liter of acid, or ppm acidity as calcium carbonate, or pH, a measure of hydrogen ion concentration.

activated alumina. Chemical used as a dryer or desiccant.

activated carbon. Specially processed carbon used as a filter-dryer; commonly used to clean air.

adiabatic process. A process that occurs without loss or gain of heat.

agitator. Device used to cause motion in confined liquid.

air-atomizing oil burner. A burner for firing oil in which oil is atomized by forcing compressed air into and through one or more streams of oil, breaking the oil into a fine spray.

air coil. Coil used with some types of heat pumps which may be used either as an evaporator or as a condenser.

air-cooled condenser. Heat of compression is transferred from condensing coils to surrounding air. This may be done by either convection or by fan or blower.

air diffuser. Air distribution outlet designed to direct air flow into desired patterns.

air-fuel ratio. The ratio of weight or volume of air to weight or volume of fuel.

air infiltration. Leakage of air into a duct, around windows or other openings.

air vent. A valved opening used for releasing air and located in the top of the highest drum of a boiler or pressure vessel.

ambient temperature. Temperature of substance (usually air) which surrounds an object on all sides. Standard ambient air conditions for performing HVAC calculations are defined as a temperature of 80 °F, relative humidity of 60 percent, and a barometric pressure of 29.921 inches Hg, giving a specific humidity of 0.013 pounds of water vapor per pound of air.

ampere. Unit of electric current equivalent to the flow of one coulomb per second.

anemometer. Instrument for measuring the velocity of air or a gas.

anode. Positive terminal of electrolytic cell.

aspect ratio. Ratio of length to width of rectangular air grille or duct.

aspirating burner. A burner in which fuel, in a gaseous or finely divided form, is burned in suspension. Air for combustion is supplied by bringing it into contact with the fuel, or combustion air is drawn through one or more openings by a lower static pressure created by velocity of the fuel stream.

aspirating psychrometer. A device which draws a sample of air through it for humidity measurement purposes.

atmospheric pressure. Pressure that gases in air exert upon the earth; measured in pounds per square inch.

atomize. Process of changing a liquid into minute particles or a fine spray.

atomizer. A device by means of which a liquid is reduced to a very fine spray.

automatic expansion valve (AEV). Pressure-controlled valve which reduces high-pressure liquid refrigerant to low-pressure liquid refrigerant.

autotransformer. A transformer in which both primary and secondary coils have turns in common. Step-up or step-down of voltage is accomplished by taps on common winding.

auxiliary air. Additional air, either hot or cold, which may be introduced into the exhauster inlet of burner lines to increase the primary air to the burners.

azeotropic mixture. Example of azeotropic mixture: refrigerant R-502 is a mixture consisting of 48.8 percent refrigerant R-22 and 51.2 percent of R-115. Refrigerants do not combine chemically, yet azeotropic mixture provides refrigerant characteristics desired.

back pressure. Pressure in low side of a refrigerating system; also called suction pressure or low-side pressure.

back-seating. When a compressor service valve is back seated the service port is closed.

baffle. Plate or vane used to direct or control movement of fluid or air within a confined area.

barometer. Instrument used for measuring atmospheric pressure. It may be calibrated in pounds per square inch or inches of mercury in a column.

beaded tube end. In a boiler, the rounded exposed end of a rolled tube when the tube metal is formed over against the sheet in which the tube is rolled.

bimetal strip. Temperature regulating or indicating device which works on principle that two dissimilar metals with unequal expansion rates, welded together, will bend as temperature changes.

bleed valve. Valve with small opening inside which permits a minimum fluid flow when the valve is closed.

blister. As related to boilers, a raised area on the surface of solid metal produced by pressure thereon while the metal is in a plastic state due to overheating.

blow back. The difference between the pressure at which a safety valve opens and at which it closes, usually about 3 percent of the pressure at which the valve opens.

blow down. Removal of a portion of boiler water for the purpose of reducing the number of concentrations or to discharge sludge.

boiler. A closed container or pressure vessel in which a liquid, usually water, is heated and may be vaporized.

boiler horsepower. An obsolete measure of boiler size. One boiler horsepower equals 33,475 Btu per hour.

boiler water. A term construed to mean a representative sample of circulating boiler water, after generated steam has been separated and before incoming feedwater or added chemical becomes mixed with it so that its composition is affected.

boiling. Conversion of a liquid into vapor with a formation of bubbles.

boiling out. Boiling of a highly alkaline water in boiler for removal of oil, grease, etc.

boiling temperature. Temperature at which a fluid changes from a liquid to a gas at a specific pressure.

bourdon tube. As used in pressure gauges, thin-walled tube of elastic metal flattened and bent into circular shape, which tends to straighten as pressure inside is increased.

Boyle's law. Law of Physics. Volume of a gas varies inversely with pressure if temperature remains the same.

breeching. A duct for the transport of products of combustion between parts of a steam generating unit or to the stack.

brine. Water saturated with chemical such as salt.

British thermal unit (Btu). Quantity of heat required to raise the temperature of one pound of water from 58.5 ^{o}F to 59.5 ^{o}F (or for general use, 1 degree F).

bulge. A local distortion or swelling outward, caused by internal pressure on a tube wall or boiler shell, caused by overheating. Also applied to similar distortion of a cylindrical furnace due to external pressure when overheated, provided the distortion is of a degree that can be driven back.

bunker c oil. Residual fuel oil of high viscosity, commonly used in large stationary steam plants (#6 fuel oil).

burner. A device for introduction of fuel and air into a furnace at desired velocities, turbulence and concentration to establish and maintain proper ignition and combustion of the fuel.

bypass. Passage at one side of, or around, regular passage.

calcium sulfate. Chemical compound ($CaSO_4$) which is used as a drying agent or desiccant in liquid line dryers.

calibrate. To adjust indicators as required to obtain accurate measurements.

capacitor. Type of electric storage device used in starting and/or running circuits on many electric motors.

capacitor-start motor. Single phase motor which has a capacitor in the starting circuit.

capillary tube. A type of refrigerant control. Usually consists of several feet of tubing having a small inside diameter.

carbon dioxide (CO_2). 1) Compound of carbon and oxygen which is sometimes used as a refrigerant. Refrigerant number is R-744. 2) Product of combustion used to determine efficiency. 3) Fire extinguishing agent.

carrene. A refrigerant (R-11). Chemical combination of carbon, chlorine and fluorine.

carry-over. Chemical solids and liquid entrained with steam from a boiler.

caustic embrittlement. A form of metal failure that occurs in steam boilers at riveted joints and at tube ends, the cracking being predominantly intercrystalline.

celsius (C). Temperature scale used in the metric system. Freezing point of water is 0; boiling point is 100. Same as centrigrade.

centrifugal compressor. Compressor which compresses gaseous refrigerants by centrifugal force.

Charles' law. A Law of Physics. The volume of a given mass of gas at a constant pressure varies with its temperature; the pressure of a given mass of gas varies with the temperature.

check valve. A device which permits fluid flow only in one direction.

chimney effect. Upward movement of air (or other gas) caused by a change in density because of heating.

choke tube. Throttling device used to maintain correct pressure difference between high-side and low-side in refrigerating mechanism. Capillary tubes are sometimes called choke tubes.

cinder. A particle or partly burned fuel larger than 100 microns in diameter.

circuit breaker. Safety device which automatically opens an electrical circuit if overloaded.

circular burner. A liquid, gaseous, or pulverized fuel burner having a circular opening through the furnace wall.

clearance pocket, compressor. A small space in cylinder from which compressed gas is not completely expelled.

clinker. A hard, compact, congealed mass of fused furnace refuse, usually slag.

combustible. Heat producing constituents of a fuel.

combustion. Rapid chemical combination of oxygen with the combustible elements of a fuel, resulting in the production of heat.

combustion rate. Quantity of fuel fired per unit of time, as pounds of coal per hour or cubic feet of gas per minute.

comfort zone. Area on psychrometric chart which shows conditions of temperature, humidity, and sometimes air movement, in which most people are comfortable.

compound gauge. Instrument for measuring pressures both above and below atmospheric pressure.

compound refrigerating systems. System which has several compressors or compressor cylinders in series. The system is used to pump low pressure vapors to condensing pressures.

compression. Term used to denote increase of pressure on a fluid by using mechanical energy.

compressor. Pump of a refrigerating mechanism which draws a vacuum or low pressure on cooling side of refrigerant cycle and squeezes or compresses the gas into the high pressure or condensing side of the cycle.

concentration, cycle of. 1) Number of times that dissolved solids have increased from the original amount in the feedwater to that in the boiler water due to evaporation in generating system. 2) A method of comparing dissolved solids in cooling tower circulating water to those in raw makeup water.

condensate. Condensed water resulting from removal of latent heat from steam.

condense. Action of changing a gas or vapor to a liquid.

condenser, boiler. A boiler in which steam is generated by the condensation of a vapor.

condenser comb. Comb-like device which is used to straighten metal fins on condensers or evaporators.

condenser, water-cooled. 1) Heat exchanger which is designed to transfer heat from hot gaseous refrigerant to water. 2) An apparatus to change the state of steam to water by passing the cooling water through tube surrounded by steam vapor.

condensing unit service valves. Shutoff hand valves mounted on refrigeration condensing unit to enable installation and/or service of the unit.

conductivity. Ability of a metal or a substance to conduct or transmit heat and/or electricity.

conductor. Substance or body capable of conducting electricity, heat, etc.

contaminant. A substance (dirt, moisture, or other substances) foreign to refrigerant or refrigerant oil in system.

controlled evaporator pressure. Controlled system which maintains definite pressure or range of pressures in evaporator.

convection. Transmission of heat by circulation or flow of a liquid or gas.

"cracking" a valve. Opening a valve a small amount.

crank throw. Distance between center line of main bearing journal and center line of the crankpin or eccentric.

current relays. Device which opens or closes a circuit based on a change of current flow.

cycle. Series of events which are repeated in the same order.

cycle of concentration. (See Concentration.)

Dalton's law. Law of Physics. Total vapor pressure of a mixture of gases is equal to the sum of individual vapor pressures of each of gases contained in the mixture.

damper. A device for introducing a variable resistance for regulating the volumetric flow of gas or air. 1) Butterfly type. A single-blade damper pivoted about its center. 2) Curtain type. A damper, composed of flexible material, moving in a vertical plane as it is rolled. 3) Flap type. A damper consisting of one or more blades, each pivoted about one edge. 4) Louvre type. A damper consisting of several blades, each pivoted about its center and linked together for simultaneous operation. 5) Slide type. A damper consisting of a single blade which is adjusted by sliding into or out of a duct through a slot in the side of the duct

deaeration. Removal of air and gases from boiler feedwater prior to introduction to a boiler.

decibel. Unit used for measuring relative loudness of sounds. One decibel approximates the minimum difference of loudness detectable by the human ear.

deflector. A device for changing direction of a stream of air or of a mixture of fuel and air.

degasification. 1) Removal of gases from samples of steam taken for purity tests. 2) Removal of carbon dioxide from water as in the ion exchange method of softening water.

degree day (heating). Unit that represents one degree of difference between 65 °F and the mean outdoor temperature of any day. Degree days are based on mean temperature over a 24-hour period. As an example; if a mean temperature for a day is 50 °F, the number of degree-days for that day would be equal to 65 °F minus 50 °F or 15 degree-days (65 °F - 50 °F = 15 °F).

dehydrated oil. Lubricant which has had most of the water content removed.

delayed combustion. A continuation of combustion beyond the furnace.

demand meter. A device that indicates or records the demand or maximum demand. Note: Since demand involves both an electrical factor and a time factor, mechanisms responsive to each of these factors are required as well as in indicating or recording mechanism. These mechanisms may be either separate from or structurally combined with one another.

density. Weight or mass per unit volume of a substance.

design load. Load for which a heating and/or cooling unit is designed.

design pressure. Maximum allowable working pressure permitted under rules of the ASME pressure vessel or boiler code.

dew point. Temperature at which water vapor (at 100 percent humidity) begins to condense as heat is removed.

diaphragm. Flexible membrane usually made of thin metal, rubber, or plastic.

differential. As applied to cooling and heating 1) Difference between "cut-in" and "cut-out" temperature or pressure of a control. 2) Pressure drop across a filter.

diffuser. 1) As applied to oil and gas burners, a metal plate with openings so placed as to protect the fuel spray from high velocity air while admitting sufficient air to promote ignition and combustion of fuel. Sometimes termed impeller. 2) Device in an air duct to direct air out of the duct.

direct expansion evaporator. An evaporator coil using either an automatic expansion valve (AEV) or a thermostatic expansion valve (TEV) refrigerant control. Room air is usually cooled by direct contact with a coil.

disengaging surface. Surface of boiler water from which steam is released.

dissolved gases. Gases which are in solution in water. (Not chemically combined)

dissolved solids. Those solids in water which are in solution. (Not chemically combined)

distilling apparatus. Fluid reclaiming device used to reclaim used refrigerants. Reclaiming is usually done by vaporizing and then recondensing refrigerant.

distillate fuels. Liquid fuels distilled usually from crude petroleum, except residuals such as #5 and #6 fuel oil which are not distillate fuels.

draft. Difference between atmospheric pressure and some lower pressure existing in a furnace or gas passages of a furnace or boiler.

draft gauge. An instrument for measuring draft or air movement, usually in inches of water. Also termed draft indicator.

drain. A valved connection at the lowest point for removal of fluid.

dryer. A substance or device used to remove moisture from a refrigeration system.

dry-bulb temperature. Air temperature as indicated by an ordinary thermometer not affected by water vapor content of air.

dry pipe. A perforated or slotted pipe or box inside a drum of a boiler and connected to the steam outlet.

dry steam. Steam which contains no moisture. Commercially dry steam containing not more than one-half of 1 percent moisture.

dry system. A refrigeration system which has an evaporator liquid refrigerant mainly in atomized or droplet condition.

dual-flow oil burner. A burner having an atomizer, usually mechanical, with two sets of tangential slots, one set being used for low capacities and the other set for high capacities.

duct. In heating and cooling, a tube or channel through which air is conveyed or moved.

ebulator. A pointed or sharp edged solid substance inserted in flooded type evaporators to improve evaporation (boiling) of refrigerant in the coil.

ebullition. An act of boiling or bubbling.

eccentric. A circle or disk mounted off center. Eccentrics are used to adjust controls and linkages.

economizer. A heat recovery device designed to transfer heat from the products of combustion to a fluid, usually boiler feedwater or combustion air or makeup air.

effective temperature. Overall effect on a human of air temperature, humidity, and air movement.

efficiency. A ratio of output to input. Efficiency of a steam generating unit is a ratio of heat absorbed by water and steam to heat in the fuel fire.

electric water valve. Solenoid type (electrically operated) valve used to turn fluid flow on and off.

electron. Elementary particle or portion of an atom which carries a negative charge.

electronic leak detector. As used in refrigeration, an electronic instrument which measures electronic flow across gas gap. Changes in electronic flow indicates presence of refrigerant gas molecules.

electronic sound tracer. Instrument used to detect leaks by locating source of high frequency sound caused by leak.

electrostatic filter. Type of filter which gives particles of dust electric charge. This causes particles to be attracted to an oppositely charged plate and removed from airstream.

enthalpy. The thermodynamic property of a substance defined as the sum of its internal energy plus pressure and volume energy (mechanical energy). Former obsolete terms are total heat or heat content.

entrainment. Conveying of particles of water or solids from the boiler water by the steam.

entropy. A mathematical factor which is a measure of the unavailable energy in a thermodynamic system. This is primarily used for theoretical calculations.

equalizer. Connection between parts of a boiler to equalize pressure.

equalizer tube. Device used to maintain equal pressure or equal liquid levels between two containers.

evaporation. A term applied to changing of a liquid to a gas. Heat is absorbed in this process.

evaporator. Part of a refrigerating mechanism in which the refrigerant vaporizes and absorbs heat.

evaporator, dry-type. An evaporator into which refrigerant is fed from a Pressure reducing device. Little or no liquid refrigerant collects in the evaporator.

evaporator, flooded. An evaporator containing liquid refrigerant at all times.

excess air. Air supplied for combustion in excess of that theoretically required for complete combustion.

expansion tank. Expansion tanks are placed in hot water heating systems to act as a cushion for the expanding water.

expansion valve. A device in a refrigerating system which maintains a pressure difference between the high-side and low-side and is operated by pressure.

explosion door. A door in a furnace or boiler setting designed to be opened by a predetermined gas pressure to relieve pressure.

external-mix oil burner. A burner having an atomizer in which the liquid fuel is struck, after it has left an orifice, by a jet of high velocity steam or air.

external treatment. Treatment of boiler feedwater prior to its introduction into the boiler.

externally-fired boiler. A boiler in which the furnace is essentially surrounded by refractory or water-cooled tubes.

Fahrenheit (F). On a Fahrenheit thermometer, under standard atmospheric pressure, boiling point of water is 212° and freezing point is 32° above zero on its scale.

fail-safe control. A control in which any component failure will cause the system or unit controlled to stop operating in a safe manner.

feedwater. Water introduced into a boiler. During operation it includes both condensate and makeup water.

feedwater treatment. Treatment of boiler feedwater by addition of chemicals to prevent formation of scale or to eliminate other objectionable characteristics.

filter. 1) Device for removing small particles from a fluid. 2) Device for removing dirt and dust from the air stream.

firebox. Equivalent of a furnace. A term used for furnaces of locomotive and similar types of boilers.

fire point. Lowest temperature at which, under specific conditions, fuel oil gives off enough vapor to burn continuously when ignited. (See Ignition Temperature.)

fire tube. A tube in a boiler having water on the outside and carrying products of combustion on the inside.

flame detector. A device which indicates if fuel is burning, or if ignition has been lost. The indication may be transmitted to a signal device or to a control system.

flame test for leaks. Use of a tool which is principally a torch and when an air-refrigerant mixture is fed to the flame, this flame will change color in presence of heated copper. (See Halide Torch.)

flapper valve. A type of check valve used in refrigeration compressors which allows gaseous refrigerants to flow in only one direction.

flareback. A burst of flame from a furnace in a direction opposed to the normal flow. Flarebacks occur when the pressure inside the furnace is greater than outside.

flare-type burner. A circular burner from which fuel and air are discharged in the shape of a cone.

flashing. Steam produced by discharging water at steam saturation temperature into a region of lower pressure.

flash gas. Instantaneous evaporation of some liquid refrigerant in an evaporator which cools the remaining liquid refrigerant to desired evaporation temperature.

flash point. Lowest temperature at which, under specific conditions, fuel oil gives off enough vapor to flash into momentary flame when ignited.

float valve. Type of valve which is operated by a sphere or pan which floats on a liquid surface and controls the level of a liquid.

flooded system. Type of refrigeration system in which liquid refrigerant fills an evaporator.

flow meter. Instrument used to measure velocity or volume of fluid movement.

flue. Gas or air passage which usually depends on natural convection to cause combustion gases to flow through it. Forced convection may sometimes be used.

fly ash. Fine particles of ash which are carried by products of combustion.

foam leak detector. A system of soap bubbles or special foaming liquids brushed over joints and connections to locate leaks.

foaming. 1) Formation of a foam in an oil refrigerant mixture due to rapid evaportion of refrigerant dissolved in the oil. 2) A continuous formation of bubbles which have sufficient high surface tension to remain as bubbles beyond the disengaging surface.

foot-pound. 1) A unit of work. A foot-pound is an amount of work done in lifting one pound one foot. 2) Also a measure of torque, i.e., turning force on a shaft or bolt. A 10 pound force perpendicular to a 2 foot wrench will produce 20 foot-pound torque.

forced circulation. Circulation of fluids by mechanical force.

force draft fan. A fan supplying air under pressure to equipment, such as a burner or cooling tower.

fouling. Accumulation of refuse in gas passages or on heat-absorbing surfaces which results in undesirable restrictions to the flow of gas or heat.

freezing. Change of state from liquid to solid.

freezing point. Temperature at which a liquid will solidify upon removal of heat at specific pressure.

fuel-air mixture. Mixture of fuel and air expressed as a ratio.

fuel oil. A liquid fuel derived from petroleum or coal. (See Distillate Fuels.)

furnace. An enclosed space provided for the combustion of fuel.

fuse. Electrical safety device consisting of a strip of fusible metal in the circuit which melts when current exceeds given value and time characteristics.

fusible plug. 1) A hollow, threaded plug having the hollow portion filled with a low melting point material, usually located at the lowest permissible water level in a boiler. 2) Used as a safety device to release refrigeration pressure in case of fire.

galvanic action. Corrosion action between two metals of different electronic activity. This action is increased in the presence of moisture.

gas. Vapor phase or state of substance.

gas-noncondensible. A gas which will not form into a liquid under given pressure-temperature conditions.

gas valve. Device for controlling the flow of gas.

gasification. A process of converting solid or liquid fuel into gaseous fuel such as the gasification of coal.

gauge cock. A valve attached to the water column or drum for checking water level.

gauge, compound. Instrument for measuring pressures both below and above atmospheric pressure.

gauge, manifold. A device constructed to hold compound and high pressure gauges and valved to control flow of fluids through them.

gauge, pressure. Instrument for measuring pressure above atmospheric pressure.

gauge, vacuum. Instrument used to measure pressures below atmospheric pressure.

ground, short circuit. A fault in an electrical circuit allowing electricity to flow into an undesirable path.

ground wire. An electrical wire which will safely conduct electricity from a device into the circuit ground in case of insulation failure.

halide refrigerants. Family of refrigerants containing halogen chemicals.

halide torch. Type of torch used to detect halogen refrigeration leaks. (See Flame Test for Leaks.)

handhole. An opening provided for access, usually not exceeding 6 inches in longest dimension.

hardness. A measure of the amount of calcium and magnesium salts in boiler water. Usually expressed as grains per gallon or ppm of calcium carbonate.

hard water. Water which contains large amounts of calcium or magnesium.

head pressure. 1) Pressure which exists in condensing side of a refrigeration system. 2) The weight of a column of water.

heat lag. When a substance is heated on one side, it takes time for the heat to travel through the substance. This is called heat lag.

heat leakage. Flow of heat through a substance is called heat leakage.

heat load. As applied to air-conditioning. Amount of heat, measured in Btu, which is removed during a period of 24 hours.

heat of fusion. The heat released in changing a substance from a liquid state to a solid state. The heat of fusion of ice is 144 Btu per pound.

heat transfer. Movement of heat from one body or substance to another. Heat may be transferred by radiation, conduction, convection or a combination of these three methods.

heating coil. A heat transfer device which releases heat.

heating control. Device which controls temperature of heat transfer unit which releases heat.

heating surface. That surface which is exposed to the heating medium for absorption and transfer of heat to the heated medium.

heating value. Amount of heat which may be obtained by burning a fuel. It is usually expressed in Btu per pounds or Btu per gallon. There are two terms 1) Higher heating value is obtained if all the water in the products of combustion is condensed. 2) Lower heating value is obtained if none of the water vapor in the products of combustion is condensed.

hermetic motor. Compressor drive motor sealed within same casing which contains compressor.

Hg (mercury). Heavy, silver, white, metallic element; only metal that is liquid at ordinary room temperature. Symbol, Hg.

high pressure cut-out. Electrical control switch operated by the high-side pressure which automatically opens electrical circuit if too high head pressure or condensing pressure is reached.

high-side. Parts of a refrigeration system which are under condensing or high-side pressure.

high-side float. Refrigerant control mechanism which controls the level of the liquid refrigerant in the high pressure side of the mechanism.

horsepower. A unit of power equal to 33,000 foot-pounds of work per minute. In electrical terms - 746 watts is equal to one horsepower.

hot-gas bypass. Piping system in a refrigeration unit which moves hot refrigerant gas from the condenser into the low-pressure side.

humidifiers. Device used to add moisture to air.

humidistat. A control that senses humidity and turns a humidifier on or off to control humidity at a desired level.

humidity. A measure of moisture in the air. Relative humidity is the ratio of quantity of vapor present in air to the greatest amount the air can hold at a given temperature.

hydrometer. Floating instrument used to measure specific gravity or specific weight of a liquid.

hydronic system. Type of heating system which circulates a heated fluid, usually water. Circulating pump is usually controlled by a thermostat.

hydrostatic test. A strength and tightness test of a closed pressure vessel. Performed by removing air and/or gas and filling the vessel with water or other incompressible fluid and raising the pressure to a test level. Since fluid under pressure is incompressible very little energy is stored in the vessel and its failure would not be an explosion hazard.

hygrometer. An instrument used to measure humidity of air.

ignition. The initiation of combustion.

ignition temperature. Lowest temperature of a fuel at which combustion becomes self-sustaining.

ignition transformer. A transformer designed to provide high voltage current. Used in many heating systems to ignite fuel.

impeller. Rotating part of a centrifugal pump or fan.

induced-draft fan. A fan exhausting hot gases from the heat absorbing equipment.

inhibitor. A substance which selectively retards a chemical action. As an example, when using acid to remove scale, an inhibitor is used to prevent acid from attacking metal.

insulation, thermal. A material used to retard a flow of heat.

internal furnace. A furnace within a boiler consisting of a straight or corrugated flue, or a firebox substantially surrounded with water-cooled heating surface, except the bottom.

internal-mix oil burner. A burner having a mixing chamber in which high velocity steam or air impinges on jets of incoming liquid fuel which is then discharged in a completely atomized form.

internal treatment. Treatment of water by introducing chemicals directly into a vessel or piping.

internally-fired boiler. A fire-tube boiler having an internal furnace such as a scotch, locomotive firebox, vertical tubular, or other type having a water-cooled plate-type furnace.

ion. An electrically charged atom or group of atoms, the electrical charge of which results when a neutral atom or group of atoms loses or gains one or more electrons.

isothermal. An action which takes place without a temperature change.

katathermometer. (also spelled catathermometer) Large bulb alcohol thermometer used to measure air velocities or atmospheric conditions by means of cooling effect.

kelvin (K). Thermometer scale on which a unit of measurement equals the celsuis degree and according to which absolute zero is 0 degree, the equivalent of -273.16 °C. Water freezes at 273.16 °K and boils at 373.16 °K.

kilowatt. Unit of electrical power equal to 1000 watts.

lagging. A covering of insulating material on piping or ducts.

latent heat. Heat energy absorbed (or released) in the process of changing state of a substance (melting, vaporization, fusion) without change in temperature or pressure.

leakage. The uncontrolled quantity of fluid or gaseous material which enters or leaves the confinement of an enclosure.

limit control. Control used to open or close electrical circuits as temperature or pressure limits are reached.

liquid indicator. Device located in the liquid line which has a glass window through which liquid flow may be observed.

liquid line. The tube which carries liquid refrigerant from the condenser or liquid receiver to the refrigerant evaporator.

liquid receiver. A cylinder connected to the condenser outlet for storage of liquid refrigerant in a system.

live steam. Steam which has not performed any of the work for which it was generated.

low side. That portion of a refrigerating system which is under the lowest evaporator pressure.

low-side float valve. Refrigerant control valve operated by the level of liquid refrigerant in the low pressure side of the system.

low-side pressure. Pressure in cooling side of refrigerating cycle.

low-pressure control. Device used to keep low-side evaporating pressure from dropping below a certain pressure.

LP, fuel (LPG). Liquified petroleum gas which is used for fuel.

manometer. Instrument for measuring pressure of gases or vapors.

manufactured gas. Fuel gas manufactured from coal, oil, etc., as differentiated from natural gas.

maximum allowable working pressure. Maximum pressure for which a pressure vessel was designed, constructed and tested.

mean effective pressure (M.E.P.). Average pressure on a surface when a changing pressure condition exists.

mean temperature (day). High temperature plus low temperature divided by two.

mechanical-atomizing oil burner. A burner which uses the pressure of oil for atomization.

mechanical draft. Differential pressure created by mechanical means.

megohm. One megohm is equal to a million ohms.

megohmmeter (megger). An instrument for measuring extremely high resistance (in the millions of ohms range).

mercury tip switch. An electrical circuit switch which uses a small quantity of mercury in a sealed glass tube to make or break electrical contact with terminals within the tube.

methanol dryer. Alcohol used to lower freezing point of water in a refrigeration system.

micro-. A prefix denoting one millionth part of unit specified.

micron. Unit of length in metric system; a thousandth part of one millimeter.

micron gauge. Instrument for measuring pressure very close to a perfect vacuum.

milli-. A prefix denoting one thousandth; example, millivolt, one thousandth of a volt.

modulating. A type of device or control which tends to adjust by increments (minute changes) rather than by either full-on or full-off operation.

molecule. Smallest portion of an element or compound that retains chemical identity with the substance in mass.

monochlorodifluoromethane. A refrigerant better known as Freon-22 or R-22.

motor control. Device to start and/or stop a motor. (Also may vary the speed)

motor starter. High capacity electric switches that are usually operated by electromagnets and incorporates circuits to limit starting currents and provide overload protection.

multifuel burner. A burner by means of which more than one fuel can be burned, either separately or simultaneously, such as pulverized fuel, oil, or gas.

multipass arrangements. Heat absorbing surfaces so baffled as to provide two or more passes in series.

multiple evaporator system. Refrigerating system with two or more evaporators connected in parallel.

natural convection or circulation. Movement of gases or fluid caused by density change due to temperature differences.

natural gas. Gaseous fuel occurring in nature.

net positive suction head. The head required at the eye of the pump impeller to prevent vaporization of the fluid (i.e., pump cavitation).

neutralizer. Substance used to counteract acids in refrigerating systems.

neutron. That part of an atom core which has no electrical potential; electrically neutral.

nominal size tubing. Tubing which has an inside diameter the same as iron pipe of the same stated size.

noncondensable gas. Gas which does not change into a liquid at normal operating temperatures and pressures.

nonferrous. Group of metals and metal alloys which contain no iron.

nozzle. A short flanged or welded neck connection on a drum or shell for the outlet or inlet of fluids; also a projecting spout through which a fluid flows.

ohm. Unit of measurement of electrical resistance, one ohm exists in a circuit when one volt causes a flow of one ampere through the circuit.

ohmmeter. An instrument for measuring resistance in ohms.

oil binding. Physical condition when an oil layer on top of refrigerant liquid hinders it from evaporating at its normal pressure-temperature conditions.

oil, refrigeration. Specially prepared oil used in refrigeration mechanisms that circulates to some extent with the refrigerant. The oil must be dry (entirely free of moisture); otherwise, moisture will condense out and freeze in the refrigerant control and may cause the refrigerant mechanism to fail. An oil classified as a refrigerant oil must be free of other contaminants and be compatible with refrigerant.

oil separator. Device used to remove oil from gaseous refrigerant.

open circuit. An interrupted electrical circuit which prevents the flow of electricity.

orifice. An accurately sized opening for controlling fluid or gaseous flow.

orsat. A gas analysis instrument in which certain gaseous constituents are measured by absorption in separate chemical solutions.

overload protector. A device, either temperature, pressure, or current operated, which will stop operation of equipment if dangerous conditions arise.

oxygen attack. Corrosion or pitting in a vessel or piping caused by oxygen.

packaged steam generator or boiler. A boiler equipped and shipped complete with fuel-burning equipment, mechanical draft equipment, automatic controls, and accessories.

partial pressure. Condition where two or more gases occupy a space and each one creates part of the total pressure.

Pascal's law. A pressure imposed upon a fluid is transmitted equally in all directions.

pass. A confined passageway containing heating and/or cooling surface, through which a fluid and/or gas flows in essentially one direction.

peak load. Maximum load carried for a stated short period of time.

perfect combustion. Complete oxidation of all the combustible constituents of a fuel, utilizing all the oxygen supplied.

pH. A hydrogen ion concentration of a solution which denotes acidity or alkalinity. A pH of 7 is neutral; a pH above 7 denotes alkalinity; while one below 7 denotes acidity. This pH number is the negative exponent of 10, representing hydrogen ion concentration in grams per liter. For instance, a pH of 7 represents 10^{-7} (0.0000001) grams per liter.

pitot tube. An instrument which will register Ram pressure and static pressure in a gaseous stream, used to determine its velocity. Ram pressure is created by moving gas hitting the face of the pitot tube. Static pressure is the pressure measured without influence of velocity.

pitting. A concentrated attack by oxygen or other corrosive elements in a vessel or piping, producing a localized depression in the metal surface.

plenum chamber. Chamber or container for moving air or other gas under a slight positive pressure.

polyphase motor. Electrical motor designed to be used with a three-phase electric circuit.

potential, electrical. An electrical force which moves, or attempts to move, electrons along a conductor or through a circuit. Measured in volts.

potential (voltage) relay. Electrical switch which is operated by voltage changes in an electromagnet.

potentiometer. Instrument for measuring or controlling electrical potential.

pour point (oil). Lowest temperature at which oil will pour or flow.

power. 1) Time rate at which work is done. 2) Source or means of supplying energy.

power element. Sensitive element of a temperature operated control.

precipitate. To separate materials from a solution by the formation of insoluble matter by chemical reaction.

preheated air. Air at a temperature exceeding that of the ambient air.

pressure. Effect of force acting over an area on a fluid. A force of 10 pounds on a piston with 10 square inches of area creates a pressure of one pound per square inch in the fluid acted on by the piston.

pressure drop. Difference in pressure between two points in a system caused by resistance to flow.

pressure limiter. Device which remains closed until a certain pressure is reached and then opens and releases fluid to another part of the system.

pressure motor control. A device which opens and closes an electrical circuit as pressures change.

pressure regulator, evaporator. An automatic pressure regulating valve. Mounted in suction line between evaporator outlet and compressor inlet. Its purpose is to maintain a predetermined pressure and temperature in an evaporator.

pressure, suction. 1) Pressure in the low-pressure side of a refrigeration system. 2) Pressure at the inlet of the suction side of a pump.

primary air. Air introduced with fuel at burners. In direct-fired systems this may be the same as pulverizer air, although in some cases pulverizer air is augmented by air bypassed around the pulverizer.

primary control. Device which directly controls the operation of a heating system.

priming. Discharge of steam containing excessive quantities of water in suspension from a boiler, due to ebullition (boiling).

products of combustion. Gases, vapors, and solids resulting from combustion of fuel.

propane. Volatile hydrocarbon used as a fuel, also as a refrigerant.

protector, circuit. An electrical device which will open an electrical circuit if excessive electrical conditions occur.

psi. A symbol or initials used to indicate pressure measured in pounds per square inch.

psia. A symbol or ititials used to indicate pressure measured in pounds per square inch absolute. Absolute pressure equals gauge pressure plus atmospheric pressure.

psig. A symbol or initials used to indicate pressure in pounds per square inch gauge. The "g" indicates that it is gauge pressure and not absolute pressure.

psychrometer or wet-bulb hydrometer. An instrument for measuring the relative humidity of air.

pull down (or evacuate). An expression indicating the action of removing refrigerant from all or part of the refrigeration system.

pump down. An act of using a compressor or a pump to reduce the pressure in a container or a system.

purging. Releasing compressed gas to atmosphere through some part or parts of a system for the purpose of removing contaminants from that part or parts.

R-11, **trichloromonofluoromethane.** Low-pressure, synthetic chemical refrigerant which is also used as a cleaning fluid.

R-12, dichlorodifluoromethane. A popular refrigerant known as Freon-12.

R-22, monochlorodifluoromethane. Synthetic chemical refrigerant also known as Freon-22.

R-113, trichlorotrifluoroethane. Synthetic chemical refrigerant.

R-170, ethane. Low-temperature application refrigerant.

R-290, propane. Low-temperature application refrigerant.

R-500. Refrigerant which is an azeotropic mixture of R-12 and R-152a.

R-502. Refrigerant which is an azeotropic mixture of R-22 and R-115.

R-503. Refrigerant which is an azeotropic mixture of R-23 and R-13.

R-504. Refrigerant which is an azeotropic mixture of R-32 and R-115.

R-600, butane. Low-temperature application refrigerant; also used as a fuel.

R-611, methyl formate. Low-pressure refrigerant.

radiant heating. Heating system in which warm or hot surfaces are used to radiate heat into the space to be conditioned.

radiation. Transfer of heat by heat rays.

rankine. Name given the absolute (Fahrenheit) scale, zero on this scale is -460 ^{o}F.

rated capacity. The manufacturer's stated capacity rating for mechanical and electrical equipment.

raw water. Water supplied before any treatment is applied.

receiver-dryer. A cylinder in a refrigeration system for storing liquid refrigerant and which also holds a quantity of desiccant.

receiver heating element. Electrical resistance heater mounted in or around a liquid receiver, used to maintain head pressures when ambient temperature is at freezing or below.

reed valve. Thin flat tempered steel plate fastened at one end over an opening so that fluid can pass in only one direction.

refrigerant. Substance used in a refrigerating mechanism to absorb heat in evaporator coil by change of state from a liquid to a gas, and to release its heat in a condenser as the substance returns from the gaseous state back to a liquid state.

refrigerant charge. Quantity of refrigerant in a system.

register. 1) An apparatus used in a burner to regulate direction of flow of air for combustion. 2) Combination grille and damper assembly located on an air opening or at the end of an air duct.

relative humidity. Ratio of the amount of water vapor present in air to the greatest amount the air can hold at the same temperature.

relay. Mechanism which uses a small signal to operate a switch or valve controlling large electric current or fluid flow.

relief valve. Safety device designed to open before dangerous pressure is reached.

remote power element control. Device with sensing element located apart from operating mechanism.

residual fuels. Products remaining from crude petroleum after removal of some of the water and an appreciable percentage of the more volatile hydrocarbons.

return-flow oil burner. A mechanical atomizing oil burner in which part of the oil supplied to the atomizer is withdrawn and returned to storage or to the oil line supplying the atomizer.

reversing valve. Device used to reverse direction of refrigerant flow depending upon whether heating or cooling is desired.

ringelmann chart. A series of four rectangular grids of black lines of varying widths printed on a white background, and used as a criterion of blackness for determining smoke density.

riser valve. Device used to control flow in vertical piping.

rolled joint. A joint made by expanding a tube into a hole by a roller expander.

rotary blade compressor. Mechanism for pumping fluid by revolving blades inside a cylindrical housing.

rotary compressor. Mechanism which pumps fluids by using rotating motion.

rotary-cup oil burner. A burner in which atomization is accomplished by feeding oil to the inside of a rapidly rotating cup.

saturated air. Air which contains the maximum amount of water vapor that it can hold at its temperature and pressure.

saturated steam. Steam at the temperature and pressure where it could become a liquid if any heat were removed.

saturated temperature. Temperature at which evaporation occurs at a particular pressure.

saturated water. Water at its boiling point.

saturation. Condition existing when a substance contains the maximum of another substance for a given temperature and pressure.

scale. A hard coating or layer of chemical materials on internal surfaces of boiler pressure parts, the inside of condenser tubes in shell and tube condensers, and the external surface of evaporative condenser tubes.

secondary air. Air for combustion supplied to the furnace to supplement primary air.

secondary combustion. Combustion which occurs as a result of ignition at a point beyond the furnace.

sensible heat. Heat which causes a change in temperature of a substance.

separator, oil. A device used to separate refrigerant oil from refrigerant gas and return the oil to the crankcase of the compressor.

sequence controls. Group of devices which act in series or in time order.

service valve. A device to be attached to a system which provides an opening for gauges and/or charging lines. Also provides a means of shutting off or opening gauge and charging ports, and controlling refrigerant flow in the system.

shell. The cylindrical portion of a pressure vessel.

shell-and-tube flooded evaporator. Device which flows water through (or around) tubes built into cylindrical evaporator.

shell-type condenser. Cylinder or receiver which contains condensing water coils or tubes.

short cycling. Refrigeration system that starts and stops more frequently than it should.

shroud. Housing over condenser or evaporator.

silica gel. Chemical compound used as a dryer, which has ability to absorb moisture. When heated moisture is released and compound may be reused.

sintered oil bearing. Porous sleeve bearing, usually bronze, which has oil in the pores of the bearing metal.

sludge. A soft water-formed sedimentary deposit which normally can be removed by blowing down a boiler or washing out a condenser using a soft brush.

slug. 1) A large "dose" of chemical treatment applied to a system intermittently. 2) Also used sometimes instead of "priming" to denote a discharge of water through a boiler steam outlet in relatively large intermittent amounts.

smoke. Small gas-borne particles of carbon or soot, less than one micron in size, resulting from incomplete combustion of carbonaceous materials and of sufficient number to be observable.

smoke test. Test made to determine completeness of combustion.

soft water. Water which contains little or no calcium or magnesium salts, or water from which scale-forming impurities have been removed or reduced.

softening. Chemical process of reducing scale-forming calcium and magnesium impurities in water.

solenoid valve. Electromagnet with a moving armature which serves as a valve, or operates a valve.

soot. Unburned particles of carbon derived from hydrocarbons.

spalling. The breaking off of the surface or refractory material as a result of internal stresses.

specific gravity. Weight of a liquid compared to water which is assigned the value of 1.0.

specific heat. Ratio of the quantity of heat required to raise the temperature of a body one degree to that required to raise the temperature of an equal mass of water one degree.

specific volume. Volume per unit mass of a substance.

split system. Refrigeration or air-conditioning installation which places condensing unit outside or remote from the evaporator.

spontaneous combustion. Ignition of combustible material following slow oxidation without the application of high temperature from an external source.

stack. A vertical conduit, which, due to the difference in density between internal and external gases, creates a draft at its base.

standard atmosphere. Air pressure of 14.7 psi (or 29.92 inches of mercury).

standard conditions. Used as a basis for air-conditioning calculations. Temperature of 68 °F, pressure of 29.92 inches of Hg and relative humidity of 30%.

steam. Water in a vapor state substantially unmixed with other gases.

strainer. Device such as a screen or filter used to retain solid particles while liquid passes through.

stratification of air. Condition in which there is little or no air movement in a room; air lies in temperature layers.

subcooling. Cooling of liquid refrigerant below its condensing temperature.

sublimation. Condition where a substance changes from a solid to a gas without becoming liquid.

suction service valve. A two-way manually-operated valve located at the inlet to the compressor, which controls suction gas flow and is used to service unit.

superheat. 1) To raise the temperature of steam above its saturation temperature. 2) Temperature of a vapor above boiling temperature of its liquid at that pressure.

superheated steam. Steam at a higher temperature than its saturation temperature.

surface blowoff. Removal of water, foam, etc., from the surface of the water in a boiler.

surge. 1) Heating - The sudden displacement or movement of water in a closed vessel or drum. 2) Cooling- Fluctuating action of temperature or pressure before it reaches its final value or setting.

surge tank. Container connected to a refrigeration system which increases gas volume and reduces rate of pressure change.

suspended solids. Undissolved solids in boiler water.

syphon seal. Corrugated metal tubing used to hold seal ring and provide leakproof connection between seal ring and compressor body or shaft.

tap-a-line. Device used to puncture or tap a line where there are no service valves available; sometimes called a saddle valve.

temperature-humidity index. Actual temperature and humidity of a sample of air, compared to air at standard conditions.

therm. A unit of heat applied especially to heating value of gas. One therm equals 100,000 Btu.

thermal relay (hot wire relay). Electrical control used to actuate a refrigeration system. This system uses a wire to convert electrical energy into heat energy.

thermocouple. Device which generates electricity, using the principle that if two dissimilar metals are welded together and junction is heated, a voltage will develop across the open ends.

thermostatic control. Device which operates a system or part of a system based on temperature changes.

thermostatic motor control. Device used to control cycling of a unit through the use of a control bulb attached to the evaporator.

thermostatic valve. Valve controlled by thermostatic elements.

thermostatic water valve. Valve used to control flow of water through a system, actuated by temperature difference. Used in units such as water-cooled compressor or condenser.

throttling. Expansion of gas through an orifice or controlled opening without gas performing any work in the expansion process.

timer thermostat. Thermostat which includes a clock mechanism. Unit automatically controls space temperature and changes it according to time of day.

ton of refrigeration. Refrigeration effect equal to the melting of one ton of ice in 24 hours. This may be expressed as follows:

28,000 Btu/24 hours
12,000 Btu/hour
200 Btu/minute

torque. Turning or twisting force.

treated water. Water which has been chemically treated to make it suitable for boiler feedwater, condensing water, and chilled water systems.

tube. A hollow cylinder for conveying fluids and gases.

tube constricted. Tubing that is reduced in diameter.

tube-within-a-tube. A water-cooled condensing unit in which a small tube is placed inside a large tube. Refrigerant passes through one tube; water passes through the other.

turbidity. The optical obstruction to the passing of a ray of light through a body of water, caused by finely divided suspended matter.

turbulent burner. A burner in which fuel and air are mixed and discharged into the furnace in such a manner as to produce turbulent flow from the burner.

unfired pressure vessel. A vessel designed to withstand internal pressure, neither subjected to heat from products of combustion, nor an integral part of a fired pressure vessel.

universal motor. Electric motor which will operate on both AC and DC current.

vacuum. Reduction of pressure in a system to less than atmospheric pressure.

valve plate. Part of a compressor located between the top of the compressor body and head which contains the compressor valves.

valve, service. Device used to check pressures and charge a refrigerating unit.

vapor. Word usually used to denote vaporized refrigerant rather than the word "gas"; also to denote steam in reference to heating.

vapor barrier. Thin plastic or metal foil sheet used to prevent water vapor from penetrating insulating material.

vapor lock. Condition where liquid in a line will not flow because the pressure and temperature condition causes the liquid to vaporize.

vapor pressure. Pressure caused by the vapors of a substance.

vapor, saturated. Condition which will result in condensation of liquid if heat is removed.

velocimeter. Instrument used to measure air velocities using a direct reading air-speed indicating dial.

viscosity. Term used to describe resistance of flow of liquids. It is measured by the time required for a fixed quantity of the liquid to flow through an orifice of given size.

volatile liquid. Liquid which evaporates at low temperature and pressure.

water column. A vertical tubular member connected at its top and bottom to the steam and water space respectively of a boiler, to which the water gauge, gauge cocks, and high- and low-level alarms may be connected.

water-cooled condenser. Condensing unit which is cooled through the use of water.

water hammer. A sudden increase in pressure of water due to an instantaneous conversion of momentum to pressure when flow is quickly stopped.

water tube. A tube in a boiler having the water and steam on the inside and heat applied to the outside.

wet-bulb. Device used in measurement of relative humidity. Evaporation of moisture lowers temperature of wet-bulb compared to dry-bulb temperature in the same area.

wet-bulb temperature. The lowest temperature which a water-wetted body will attain when exposed to an air current. This is the temperature of adiabatic saturation.

APPENDIX A

TABLES

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TABLE 1

AIR-CONDITIONING DATA

Outdoor design temperatures (winter and summer) and degree days (heating) for typical cities in the United States. From ASHRAE Handbook of Fundamentals and General Electric Co. Winter design is the median of the annual lowest temperatures over 25 years. Summer design is that temperature which is equalled or exceeded approximately 29 hours during a normal summer.

Winter Design Temp °F	Degree Days (Heating)	City	Summer Design dbt °F	Summer Design wbt °F
14	2961	Atlanta, GA	95	78
8	4654	Baltimore, MD	94	79
-1	5634	Boston, MA	91	76
-3	7062	Buffalo, NY	88	75
-7	6155	Chicago, IL	95	78
2	4410	Cincinnati, OH	94	78
-2	6351	Cleveland, OH	91	76
-1	5660	Columbus, OH	92	77
14	2363	Dallas, TX	101	79
-9	6283	Denver, CO	92	65
0	6232	Detroit, MI	92	76
58	0	Honolulu, HI	87	75
23	1396	Houston, TX	96	80
-5	5699	Indianapolis, IN	93	78
26	1239	Jacksonville, FL	96	80
-2	4711	Kansas City, MO	100	79
36	2061	Los Angeles, CA	86	69
11	3232	Memphis, TN	98	80
-11	7635	Milwaukee, WI	90	77
-19	8382	Minneapolis, MN	92	77
6	3578	Nashville, TN	97	79
6	4589	Newark, NJ	94	77
29	1385	New Orleans, LA	93	81
6	4871	New York, NY	94	77
7	5144	Philadelphia, PA	93	78
25	1765	Phoenix, AZ	108	77
-1	5987	Pittsburgh, PA	90	77
17	4635	Portland, OR	89	69
-2	4900	St. Louis, MO	98	79
22	1546	San Antonio, TX	99	77
38	1458	San Diego, CA	86	71
32	3015	San Francisco, CA	83	65
30	NA	San Jose, CA	90	69
22	4424	Seattle, WA	81	67
-5	6494	Toledo, OH	92	77
12	4224	Washington, DC	94	78

TABLE 2

ATMOSPHERIC PRESSURES AND BAROMETER READINGS AT DIFFERENT ALTITUDES (APPROXIMATE VALUES)

Altitude Below or Above Sea Level Feet	Barometer Reading Inches Merc at 32 °F	Atmospheric Pressure Lb-Sq In	Equivalent Head of Water (75 °F) Feet	Boiling Point of Water °F
-1000	31.02	15.2	35.2	213.8
- 500	30.47	15.0	34.7	212.9
0	29.921	14.7	34.0	212.0
+ 500	29.38	14.4	33.4	211.1
+1000	28.86	14.2	32.8	210.2
1500	28.33	13.9	32.2	209.3
2000	27.82	13.7	31.6	208.4
2500	27.31	13.4	31.0	207.4
3000	26.81	13.2	30.5	206.5
3500	26.32	12.9	29.9	205.6
4000	25.84	12.7	29.4	204.7
4500	25.36	12.4	28.8	203.8
5000	24.89	12.2	28.3	202.9
5500	24.43	12.0	27.8	201.9
6000	23.98	11.8	27.3	201.0
6500	23.53	11.5	26.7	200.1
7000	23.09	11.3	26.2	199.2
7500	22.65	11.1	25.7	198.3
8000	22.22	10.9	25.2	197.4
8500	21.80	10.7	24.8	196.5
9000	21.38	10.5	24.3	195.5
9500	20.98	10.3	23.8	194.6
10,000	20.58	10.1	23.4	193.7
15,000	16.88	8.3	19.1	184.0
20,000	13.75	6.7	15.2	-
30,000	8.88	4.4	10.2	-
40,000	5.54	2.7	6.3	-
50,000	3.44	1.7	3.9	-

TABLE 3

CONVERSION FACTORS

To Convert from	To	Multiply by #
Angstrom unit	centimeters	1.000 E-08
Atmospheres	mm of mercury at 0 °C	7.600 E+02
	pounds/sq in	1.470 E+01
	kilograms/sq m	1.033 E+04
Bars	dynes/sq cm	1.000 E+06
Btu	foot-pounds	7.776 E+02
	horsepower-hours	3.928 E-04
	kilogram-calories*	2.520 E-01
	kilowatt-hours	2.929 E-04
Btu*/hour	horsepower	3.928 E-04
Btu*/(hour-sq ft) (°F/in)	(gram-cal*/s.-sq cm) (°C/cm)	3.445 E-04
Btu*/minute	foot-pound/s	1.296 E+01
	horsepower	2.357 E-02
	kilowatts	1.757 E-02
Btu*/second	kilopound-meters/s	1.075 E+02
	kilowatts	1.054 E+00
Btu*/sq.ft	gram-cal*/sq cm	2.712 E-01
Centimeters Hg (0 °C)	pounds-force/sq in	1.9337E-01
	inches of water	5.353 E+00
Centipoises	pound/foot-hours	2.420 E+00
Cubic feet/minute	gallons/second	1.247 E-01
	cubic cm/s	4.720 E+02
Cubic feet/pound	cu cm/g	6.243 E+01
Cubic feet/second	gallons/minute	4.488 E+02
Cubic meters	cubic feet	3.531 E+01
Dynes	grams-force	1.0197E-03
Dynes-centimeters	pounds-force-feet	7.380 E-08
Dynes/sq centimeter	atmospheres	9.869 E-07
Feet of H_2O at 39.2 °F	inches of Hg of 32 °F	8.825 E-01
Foot-pounds-force	Btu*	1.286 E-03
	kilowatt-hours	3.366 E-07
Foot-pounds-force/s	Btu*/min	7.716 E-02
Gallons (U.S. Liquid)	cubic inches	2.310 E+02
	cubic feet	1.337 E-01
Gal/min (of water)	pound/hr of water	5.008 E+02
Gram-calories*	Btu	3.968 E-03
Gram-cal*/sq cm	Btu*/sq ft	3.687 E+00
Gram-force-cm	Btu*	9.301 E-08
	ergs	9.807 E+02
Grams-force	dynes	9.807 E+02
Grams	pounds	2.205 E-03
Grams/cu cm	pounds/cu in	3.613 E-02
	pounds/cu foot	6.243 E+01
Grams-force/sq cm	centimeters of Hg	7.356 E-02
	atmosphere	9.678 E-04
	pounds	2.048 E+00
Horsepower (mech)	foot-pounds-force/s	5.500 E+02
	kilowatts	7.457 E-01
Horsepower hours	Btu*	2.546 E+03
	joule (abs)	2.685 E+06
	kilogram-cal*	6.416 E+02
In of Hg at 32 °F	pounds-force/sq in.	4.912 E-01
In of H_2O at 39.2 °F (4 °C)	centimeters of Hg	1.868 E-01
	pounds-force/sq ft.	5.202 E+00
Joules (abs)	kilogram-calories*	2.390 E-04
Kilogram-cal*	horsepower-hours	1.559 E-03
Kilopond-meter	Btu*	9.301 E-03
	ergs	9.807 E+07
Kilowatt hours	average noon sunlight on 1 sq m	1.000 E+00
	Btu*	3.414 E+03
Kilowatt	horsepower hours	1.341 E+00
Kilowatts	kilogram-cal*/minute	1.434 E+01
Liter-atmospheres	Btu*	9.610 E-02
Liters/kilogram	cubic ft/pound	1.602 E-02
Liters/minute	cubic feet/sec	5.885 E-04
	gallons/hour	1.585 E+01
Newtons	dynes	1.000 E+05
Newton-meters	joules	1.000 E+00
Pound-celsius (Centigrade) Unit	Btu*	1.800 E+00
Pound-mol gas	cubic feet of gas (60 °F at 1 atm)	3.794 E+02
Pounds of H_2O (4 °C)	gallons of H_2O	1.198 E-01
Pounds of H_2O at 64 °F	cubic feet of H_2O	1.603 E-02
Pounds/gallon	grams/cu cm	1.198 E-01
Pounds/sq in	atmospheres	6.805 E-02
Watt-hour	Btu*	3.414 E+00
Watts	foot-lb/minute	4.425 E+01
	horsepower	1.341 E-03
	lumens	6.830 E+02

* Thermochemical

TABLE 4

DECIMAL AND METRIC EQUIVALENTS OF COMMON FRACTIONS OF AN INCH

FRACTION	DECIMAL	Mm	FRACTION	DECIMAL	Mm
1/64	0.01562	0.397	33/64	0.51562	13.097
1/32	0.03125	0.794	17/32	0.53125	13.494
3/64	0.04688	1.191	35/64	0.54688	13.891
1/16	0.06250	1.588	9/16	0.56250	14.288
5/64	0.07812	1.984	37/64	0.57812	14.684
3/32	0.09375	2.381	19/32	0.59375	15.081
7/64	0.10938	2.778	39/64	0.60938	15.478
1/8	0.12500	3.175	5/8	0.62500	15.875
9/64	0.14062	3.572	41/64	0.64062	16.272
5/32	0.15625	3.969	21/32	0.65625	16.669
11/64	0.17188	4.366	43/64	0.67188	17.066
3/16	0.18750	4.763	11/16	0.68750	17.463
13/64	0.20312	5.159	45/64	0.70312	17.859
7/32	0.21875	5.556	23/32	0.71875	18.256
15/64	0.23438	5.953	47/64	0.73438	18.653
1/4	0.25000	6.350	3/4	0.75000	19.050
17/64	0.26562	6.747	49/64	0.76562	19.447
9/32	0.28125	7.144	25/32	0.78125	19.844
19/64	0.29688	7.541	51/64	0.79688	20.241
5/16	0.31250	7.938	13/16	0.81250	20.638
21/64	0.32812	8.334	53/64	0.82812	21.034
11/32	0.34375	8.731	27/32	0.84375	21.431
23/64	0.35938	9.128	55/64	0.85938	21.828
3/8	0.37500	9.525	7/8	0.87500	22.225
25/64	0.39062	9.922	56/64	0.89062	22.622
13/32	0.40625	10.319	29/32	0.90625	23.019
27/64	0.42188	10.716	59/64	0.92188	23.416
7/16	0.43750	11.113	15/16	0.93750	23.813
29/64	0.45312	11.509	61/64	0.95312	24.209
15/32	0.46875	11.906	31/32	0.96875	24.606
31/64	0.48438	12.303	63/64	0.98438	25.003
1/2	0.50000	12.700	1/1	1.00000	25.400

TABLE 5

MEASURES AND WEIGHTS
(Based on National Bureau of Standards)

A. Standard

Length

1 inch	= 1000 mils	1 furlong	= 40 rods
1 foot	= 12 inches	1 statute mile	= 8 furlongs
1 yard	= 3 feet	1 statute mile	= 5,280 feet
1 fathom	= 6 feet	1 nautical mile	= 6,076 feet
1 rod	= 5-1/2 yards	1 league	= 3 miles

Area

1 sq foot	= 144 sq inches	1 acre	= 160 sq rods
1 sq yard	= 9 sq feet	1 acre	= 43,560 sq feet
1 sq rod	= 30-1/4 sq yards	1 sq mile	= 640 acres

Liquid Capacity

1 gill	= 4 fluid ounces	1 barrel	= 31-1/2 gallons
1 pint	= 4 gills	1 hogshead	= 2 bbl. (63 gal.)
1 quart	= 2 pints	1 tun	= 252 gallons
1 gallon	= 4 quarts	1 barrel (petro)	= 42 gallons

Dry Capacity

2 pints	= 1 quart	= 67.2 cu in
8 quarts	= 1 peck	= 537.6 cu in
4 pecks	= 1 bushel	= 2,150.4 cu in

Avoirdupois Weight
(For other than drugs, gold, silver, etc.)

1 dram	= 27.34 grains	1 quarter	= 25 pounds
1 ounce	= 16 drams	1 short ton	= 2,000 pounds
1 pound	= 16 ounces	1 long ton	= 2,240 pounds

1 lb avdp = 7,000 grains = 453.59 grams = 1.2153 lb troy = 1.2153 lb apoth
1 grain = 1 grain troy = 1 grain apoth

TABLE 5 (Continued)

B. Metric Equivalents

Length

Cm	= 0.3937 in	In	= 2.5400 cm
Metre	= 3.281 ft	Ft	= 0.3048 m
Metre	= 1.0936 yd	Yd	= 0.9144 m
Km	= 0.6214 mile	Mile	= 1.6093 km

Area

Sq cm	= 0.1550 sq in	Sq in	= 6.4516 sq cm
Sq m	= 10.764 sq ft	Sq ft	= 0.0929 sq m
Sq km	= 0.3861 sq mile	Sq mile	= 2.590 sq km

Volume

Cm cm	= 0.06102 cu in	Cu in	= 16.387 cu cm
Cu m	= 35.31 cu ft	Cu ft	= 0.02832 cu m

Capacity

Litre	= 61.024 cu in	Cu in	= 0.0164 litre
Litre	= 0.0353 cu ft	Cu ft	= 28.32 litres
Litre	= 0.2642 gal (U.S.)	Gal	= 3.785 litres
Litre	= 0.0284 bu (U.S.)	Bu	= 35.24 litres

Litre = { 1,000.000 cu cm
{ 1.0567 qt (liquid) or 0.9081 qt (dry)
{ 2,2046 lb of pure water at 4 °C = 1 kg

Weight

Gram	= 15.4324 grains	Grain	= 0.0648 g
Gram	= 0.03532 oz avdp	Oz avdp	= 28.35 g
Kg	= 2.2046 lb avdp	Lb avdp	= 0.4536 kg
Kg	= 0.00110 ton (sht)	Ton (sht)	= 907.2 kg

Pressure

Kg per sq cm	= 14.223 lb per sq in
Lb per sq in	= 0.0703 kg per sq cm
Kg per sq m	= 0.2048 lb per sq ft
Lb per sq ft	= 4.882 kg per sq m
Kg per sq cm	= 0.9679 normal atmosphere
Normal atmosphere	= {1.0332 kg per sq cm {1.0133 bars {14.696 lb per sq in
Pascals	= 0.000145 lb/sq in
Megapascals	= 145 lb/sq in
lb per sq in	= 6894.7 pascals

TABLE 6

MOTOR FRAME DIMENSIONS

FRAME	D	E	2F	H	U	BA	V min.	KEY WIDTH	KEY THICK.	KEY LENGTH
48	3	2-1/8	2-3/4	11/32	1/2	2-1/2			3/64 Flat	
56	3-1/2	2-7/16	3	11/32	5/8	2-3/4		3/16	3/16	1-3/8
143	3-1/2	2-3/4	4	11/32	3/4	2-1/4	1-3/4	3/16	3/16	1-3/8
143T	3-1/2	2-3/4	4	11/32	7/8	2-1/4	2	3/16	3/16	1-3/8
145	3-1/2	2-3/4	5	11/32	3/4	2-1/4	1-3/4	3/16	3/16	1-3/8
145T	3-1/2	2-3/4	5	11/32	7/8	2-1/4	2	3/16	3/16	1-3/8
182	4-1/2	3-3/4	4-1/2	13/32	7/8	2-3/4	2	3/16	3/16	1-3/8
182T	4-1/2	3-3/4	4-1/2	13/32	1-1/8	2-3/4	2-1/2	1/4	1/4	1-3/4
184	4-1/2	3-3/4	5-1/2	13/32	7/8	2-3/4	2	3/16	3/16	1-3/8
184T	4-1/2	3-3/4	5-1/2	13/32	1-1/8	2-3/4	2-1/2	1/4	1/4	1-3/4
213	5-1/4	4-1/4	5-1/2	13/32	1-1/8	3-1/2	2-3/4	1/4	1/4	2
213T	5-1/4	4-1/4	5-1/2	13/32	1-3/8	3-1/2	3-1/8	5/16	5/16	2-3/8
215	5-1/4	4-1/4	7	13/32	1-1/8	3-1/2	2-3/4	1/4	1/4	2
215T	5-1/4	4-1/4	7	13/32	1-3/8	3-1/2	3-1/8	5/16	5/16	2-3/8
254U	6-1/4	5	8-1/4	17/32	1-3/8	4-1/4	3-1/2	5/16	5/16	2-3/4
254T	6-1/4	5	8-1/4	17/32	1-5/8	4-1/4	3-3/4	3/8	3/8	2-7/8
256U	6-1/4	5	10	17/32	1-3/8	4-1/4	3-1/2	5/16	5/16	2-3/4
256T	6-1/4	5	10	17/32	1-5/8	4-1/4	3-3/4	3/8	3/8	2-7/8
284U	7	5-1/2	9-1/2	17/32	1-5/8	4-3/4	4-5/8	3/8	3/8	3-3/4
284T	7	5-1/2	9-1/2	17/32	1-7/8	4-3/4	4-3/8	1/2	1/2	3-1/4
284TS	7	5-1/2	9-1/2	17/32	1-5/8	4-3/4	3	3/8	3/8	1-7/8
286U	7	5-1/2	11	17/32	1-5/8	4-3/4	4-5/8	3/8	3/8	3-3/4
286T	7	5-1/2	11	17/32	1-7/8	4-3/4	4-3/8	1/2	1/2	3-1/4
286TS	7	5-1/2	11	17/32	1-5/8	4-3/4	3	3/8	3/8	1-7/8
324U	8	6-1/4	10-1/2	21/32	1-7/8	5-1/4	5-3/8	1/2	1/2	4-1/4
324S	8	6-1/4	10-1/2	21/32	1-5/8	5-1/4	3	3/8	3/8	1-7/8
324T	8	6-1/4	10-1/2	21/32	2-1/8	5-1/4	5	1/2	1/2	3-7/8
324TS	8	6-1/4	10-1/2	21/32	1-7/8	5-1/4	3-1/2	1/2	1/2	2
326U	8	6-1/4	12	21/32	1-7/8	5-1/4	5-3/8	1/2	1/2	4-1/4
326S	8	6-1/4	12	21/32	1-5/8	5-1/4	3	3/8	3/8	1-7/8
326T	8	6-1/4	12	21/32	2-1/8	5-1/4	5	1/2	1/2	3-7/8
326TS	8	6-1/4	12	21/32	1-7/8	5-1/4	3-1/2	1/2	1/2	2
364U	9	7	11-1/4	21/32	2-1/8	5-7/8	6-1/8	1/2	1/2	5
364US	9	7	11-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2	1/2	2
364T	9	7	11-1/4	21/32	2-3/8	5-7/8	5-5/8	5/8	5/8	4-1/4
364TS	9	7	11-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2	1/2	2
365U	9	7	12-1/4	21/32	2-1/8	5-7/8	6-1/8	1/2	1/2	5
364US	9	7	12-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2	1/2	2
365T	9	7	12-1/4	21/32	2-3/8	5-7/8	5-5/8	5/8	5/8	4-1/4
365TS	9	7	12-1/4	21/32	1-7/8	5-7/8	3-1/2	1/2	1/2	2
404U	10	8	12-1/4	13/16	2-3/8	6-5/8	6-7/8	5/8	5/8	5-1/2
404US	10	8	12-1/4	13/16	2-1/8	6-5/8	4	1/2	1/2	2-3/4
404T	10	8	12-1/4	13/16	2-7/8	6-5/8	7	3/4	3/4	5-5/8
404TS	10	8	12-1/4	13/16	2-1/8	6-5/8	4	1/2	1/2	2-3/4
405	10	8	13-3/4	13/16	2-1/8	6-5/8	6-1/8	1/2	1/2	5
405U	10	8	13-3/4	13/16	2-3/8	6-5/8	6-7/8	5/8	5/8	5-1/2
405US	10	8	13-3/4	13/16	2-1/8	6-5/8	4	1/2	1/2	2-3/4
405T	10	8	13-3/4	13/16	2-7/8	6-5/8	7	3/4	3/4	5-5/8
405TS	10	8	13-3/4	13/16	2-1/8	6-5/8	4	1/2	1/2	2-3/4
444U	11	9	14-1/2	13/16	2-7/8	7-1/2	8-3/8	3/4	3/4	7
444US	11	9	14-1/2	13/16	2-1/8	7-1/2	4	1/2	1/2	2-3/4
444T	11	9	14-1/2	13/16	3-3/8	7-1/2	8-1/4	7/8	7/8	6-7/8
444TS	11	9	14-1/2	13/16	2-3/8	7-1/2	4-1/2	5/8	5/8	3
445U	11	9	16-1/2	13/16	2-7/8	7-1/2	8-3/8	3/4	3/4	7
445US	11	9	16-1/2	13/16	2-1/8	7-1/2	4	1/2	1/2	2-3/4
445T	11	9	16-1/2	13/16	3-3/8	7-1/2	8-1/4	7/8	7/8	6-7/8
445TS	11	9	16-1/2	13/16	2-3/8	7-1/2	4-1/2	5/8	5/8	3
447TS	11	9	20	13/16	2-3/8	7-1/2	4-1/2	5/8	5/8	3
449TS	11	9	25	13/16	2-3/8	7-1/2	4-1/2	5/8	5/8	3

TABLE 7

MOTOR FULL-LOAD CURRENTS

3-Phase A.C. Induction Type - Squirrel Cage and Wound Rotor

HP	115V	200V	230V	460V	575V	2300V	4160V
1/2	4	2.3	2	1	.8		
3/4	5.6	3.2	2.8	1.4	1.1		
1	7.2	4.15	3.6	1.8	1.4		
1-1/2	10.4	6	5.2	2.6	2.1		
2	13.6	7.8	6.8	3.4	2.7		
3		11	9.6	4.8	3.9		
5		17.5	15.2	7.6	6.1		
7-1/2		25	22	11	9		
10		32	28	14	11		
15		48	42	21	17		
20		62	54	27	22		
25		78	68	34	27		
30		92	80	40	32		
40		120	104	52	41		
50		150	130	65	52		
60		177	154	77	62	16	8.9
75		221	192	96	77	20	11
100		285	248	124	99	26	14.4
125		385	312	156	125	31	17
150		415	360	180	144	37	20.5
200		550	480	240	192	49	27
Over 200HP Approximate Amperes/HP		2.75	2.40	1.20	.96	.24	.133

TABLE 8

PSYCHROMETRIC CHART

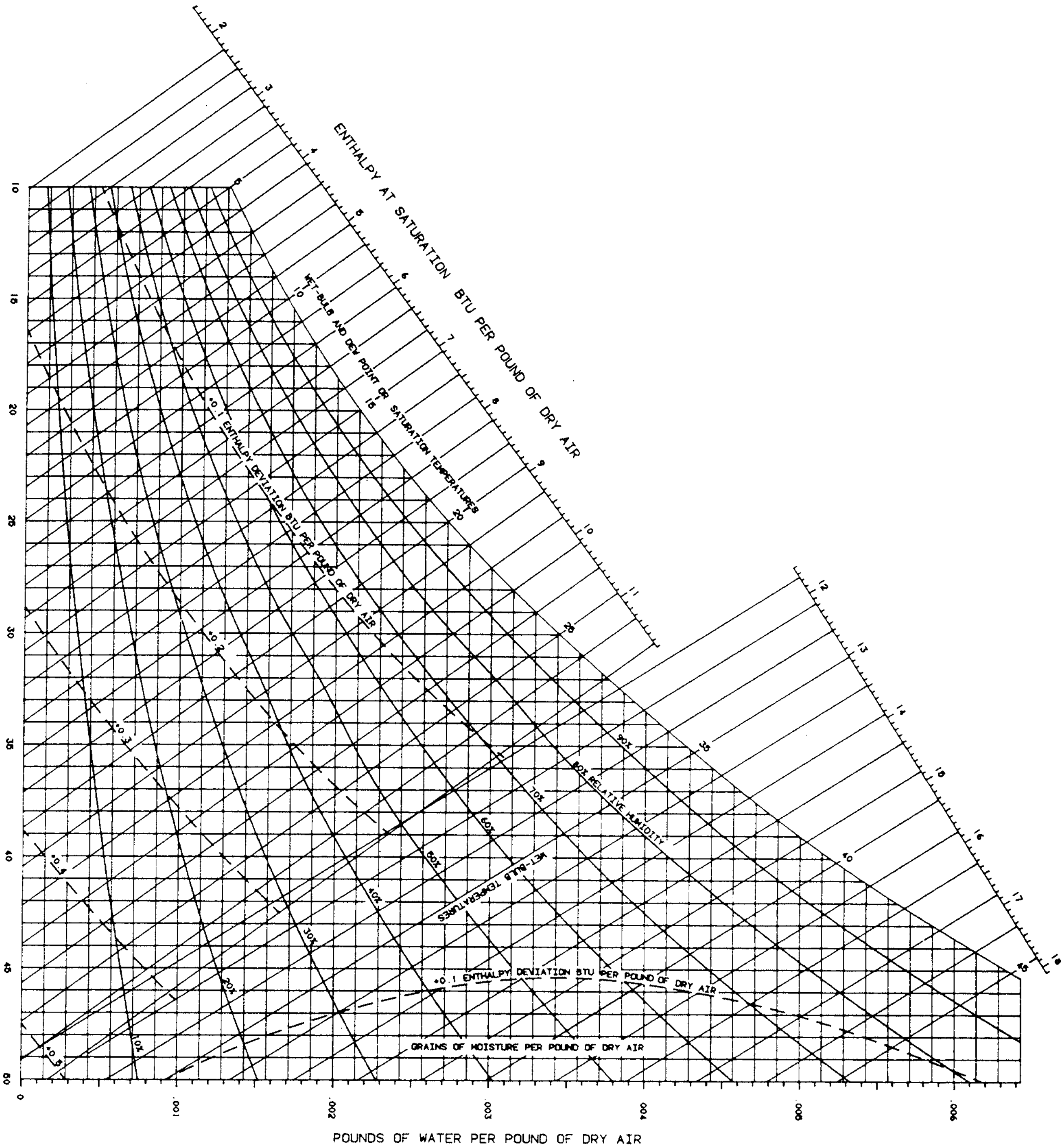

TABLE 9

REFRIGERANT PRESSURE vs TEMPERATURE
ASHRAE Handbook

Temp (°F)	Pressures in psi gauge at sea level R-12	R-22	R-502	R-717 (NH_3)
-40	11.0*	0.5	4.1	8.7*
-35	8.4*	2.6	6.5	5.4*
-30	5.5*	4.9	9.2	1.6*
-25	2.3*	7.4	12.1	1.3
-20	0.6*	10.1	15.3	3.6
-15	2.4	13.2	18.8	6.2
-10	4.5	16.5	22.6	9.0
- 5	6.7	20.1	26.7	12.2
0	9.2	24.0	31.1	15.7
5	11.8	28.2	35.9	19.6
10	14.6	32.8	41.0	23.8
15	17.7	37.7	46.5	28.4
20	21.0	43.0	52.5	33.5
25	24.6	48.8	58.8	39.0
30	28.5	54.9	65.6	45.0
35	32.6	61.5	72.8	51.6
40	37.0	68.5	80.5	58.6
45	41.7	76.0	88.7	66.3
50	46.7	84.0	97.4	74.5
55	52.0	92.6	106.6	83.4
60	57.7	101.6	116.4	92.9
65	63.8	111.2	126.7	103.1
70	70.2	121.4	137.6	114.1
75	77.0	132.2	149.1	125.8
80	82.4	143.6	161.2	138.3
85	91.8	155.7	174.0	151.7
90	99.8	168.4	187.4	165.9
95	108.2	181.8	201.4	181.1
100	117.2	195.9	216.2	197.2
105	126.6	210.8	231.7	214.2
110	136.4	226.4	247.9	232.3
115	146.8	242.7	264.9	251.5
120	157.6	259.9	282.7	271.7
125	169.1	277.9	301.4	293.1
130	181.0	296.8	320.8	
135	193.5	316.6	341.3	
140	206.6	337.2	362.6	

*In. Hg below std atmosphere

TABLE 10

VALUES OF GAS CONSTANT (R) FOR COMMON SUBSTANCES

Material	R
Air	53.34
Carbon Dioxide	38.82
Ether	23.11
Oxygen	48.55
Alcohol	41.55
Water Vapor	83.23

TABLE 11

TEMPERATURE CONVERSION TABLE

Locate Known temperature in °C/°F column. Read converted temperature in °C or °F column.

C°	°C/°F	°F	°C	°C/°F	°F	°C	°C/°F	°F
-45.4	-50	-58	15.5	60	140	76.5	170	338
-42.7	-45	-49	18.3	65	149	79.3	175	347
-40	-40	-40	21.1	70	158	82.1	180	356
-37.2	-35	-31	23.9	75	167	85	185	365
-34.4	-30	-22	26.6	80	176	87.6	190	374
-32.2	-25	-13	29.4	85	185	90.4	195	383
-29.4	-20	- 4	32.2	90	194	93.2	200	392
-26.6	-15	5	35	95	203	96	205	401
-23.8	-10	14	37.8	100	212	98.8	210	410
-20.5	- 5	23	40.5	105	221	101.6	215	419
-17.8	0	32	43.4	110	230	104.4	220	428
-15	5	41	46.1	115	239	107.2	225	437
-12.2	10	50	48.9	120	248	110	230	446
- 9.4	15	59	51.6	125	257	112.8	235	455
- 6.7	20	68	54.4	130	266	115.6	240	464
- 3.9	25	77	57.1	135	275	118.2	245	473
- 1.1	30	86	60	140	284	120.9	250	482
1.7	36	95	62.7	145	293	123.7	255	491
4.4	40	104	65.5	150	302	126.5	260	500
7.2	45	113	68.3	155	311	129.3	265	509
10	50	122	71	160	320	132.2	270	518
12.8	55	131	73.8	165	329	135	275	527

$°F = (9/5 \times °C) + 32$

$°C = 5/9\ (°F - 32)$

TABLE 12

WATER/STEAM TABLE

Gauge Pressure psig	Temperature °F	Saturated Liquid (Heat) of Liquid) Btu/lb	Evaporation (Latent Heat of Evap.) Btu/lb	Saturated Vapor (Total Heat of Steam) Btu/lb
-	32	0	-	-
-	50	18.1	-	-
-	100	68.0	-	-
-	125	93.0	-	-
-	150	118.0	-	-
-	175	143.0	-	-
-	200	168.1	-	-
-	212	180.1	-	-
0	212	180.0	970.0	1150.4
1.3	216.3	184.4	967.6	1152.0
2.3	219.4	187.6	965.5	1153.1
3.3	222.4	190.6	963.6	1154.2
4.3	225.2	193.4	961.9	1155.3
5.3	228.0	196.2	960.1	1156.3
6.3	230.6	198.8	958.4	1157.2
8.3	235.5	203.8	995.2	1159.0
10.3	240.1	208.4	952.1	1160.6
12.3	244.4	212.8	949.3	1162.1
15.3	250.3	218.8	945.3	1154.1
20.3	259.3	227.9	939.2	1167.1
25.3	267.3	236.0	933.7	1169.7
50.3	298.0	267.5	911.6	1179.1
75.3	320.3	290.6	894.7	1185.3
100.3	338.1	309.1	880.6	1169.7
125.3	353.0	324.8	868.2	1193.0
151.3	366.5	339.1	856.6	1195.7
175.3	377.5	350.8	846.8	1197.6
200.3	387.9	361.9	837.4	1199.3
225.3	397.4	372.1	828.5	1200.6
250.3	406.1	381.6	820.1	1201.7
275.3	414.2	390.5	812.1	1202.6
305.3	423.3	400.4	803.0	1203.4

TABLE 13

WATER VAPOR PER POUND
OF DRY AIR WHEN SATURATED

Temperature °F	Water Vapor Grain per Pound
105	354
100	301
95	256
90	218
85	184
80	156
75	131
70	110
65	93
60	77
55	64
50	54
40	36
30	24
20	15
10	9
0	5.5

APPENDIX B

GENERAL LAWS AND FORMULAS

TABLE OF CONTENTS

GENERAL LAWS

BOYLE'S LAW (CONSTANT TEMPERATURE)

The volume of a gas varies inversely with the absolute pressure, provided the temperaure remains constant. This means that if a certain quantity of gas has its pressure doubled, (without a change in temperature) the volume becomes one-half that of the original. Or, if the volume is doubled, the gas has its pressure reduced by one-half.

$$Po \times Vo = Pn \times Vn$$

Where Po and Vo are the old pressure and volume, Pn and Vn are the new pressure and volume.

CHARLES' LAW (CONSTANT PRESSURE OR CONSTANT VOLUME)

At a constant pressure, the volume of a confined gas varies directly as the absolute temperature. At a constant volume, the pressure varies directly as the absolute temperature.

At constant pressure: $Vo \times Tn = Vn \times To$

At constant volume: $Po \times Tn = Pn \times To$

Where:

To = Old temperature (absolute)

Tn = New temperature (absolute)

Vo = Old volume

Vn = New volume

DALTON'S LAW

The total pressure of a mixture of gases is the sum of the partial pressures of each of the gases in the mixture; i.e., the total pressure of air is the sum of the partial pressures of oxygen, nitrogen, carbon dioxide, and water vapor.

GAS LAWS COMBINED

Boyle's Law and Charles' Law may be combined to solve true gas problems and the formula is:

$$\frac{Po \times Vo}{To} = \frac{Pn \times Vn}{Tn}$$

Absolute values for temperatures and pressures must be used in this equation. Another useful formula is:

$$PV = WRT$$

Where:

P = Pressure in pounds per square foot ABS.

V = Volume in cubic feet.

W = Weight of gas in pounds.

T = Absolute temperature ^{o}F.

R = Gas constant depending on properties of the gas. Table 10, Appendix A lists the value of R for several common gases.

OHMS LAW

Ohms = Volts/Amperes
Amperes = Volts/Ohms
Volts = Amperes x Ohms

GENERAL FORMULAS

Power - A.C. Circuits:

$$\text{Efficiency} = \frac{746 \times \text{Output Horsepower}}{\text{Input Watts}}$$

$$\text{Three Phase Kilowatts} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}{1000}$$

$$\text{Three Phase Volt-Amperes} = \text{Volts} \times \text{Amperes} \times 1.732$$

$$\text{Three Phase Amperes} = \frac{746 \times \text{Horsepower}}{1.732 \times \text{Volts} \times \text{Efficiency} \times \text{Power Factor}}$$

$$\text{Three Phase Efficiency} = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.732}$$

$$\text{Three Phase Power Factor} = \frac{\text{Input Watts}}{\text{Volts} \times \text{Amperes} \times 1.732}$$

$$\text{Single Phase Kilowatts} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}{1000}$$

$$\text{Single Phase Amperes} = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Efficiency} \times \text{Power Factor}}$$

$$\text{Single Phase Efficiency} = \frac{746 \times \text{Horsepower}}{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}$$

$$\text{Single Phase Power Factor} = \frac{\text{Input Watts}}{\text{Volts} \times \text{Amperes}}$$

$$\text{Horsepower (3 Phase)} = \frac{\text{Volts} \times \text{Amperes} \times 1.732 \times \text{Efficiency} \times \text{Power Factor}}{746}$$

$$\text{Horsepower (1 Phase)} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor}}{746}$$

Motor Application Formulas:

$$\text{Torque (lb-ft.)} = \frac{\text{Horsepower} \times 5250}{\text{RPM}}$$

$$\text{Horsepower} = \frac{\text{Torque (lb-ft.)} \times \text{RPM}}{5250}$$

For Pumps:

$$\text{Horsepower} = \frac{\text{GPM x Head in Feet x Specific Gravity}}{\text{3960 x Efficiency of Pump}}$$

For Fans and Blowers:

$$\text{Horsepower} = \frac{\text{CFM x Pressure (pounds-sq/ft.)}}{\text{33000 x Efficiency}}$$

Flow Rate of Steam:

Formula:

$$W_{fs} = \frac{d_p d\, w^6}{360L(d + 3.6)}$$

Where: W_{fs} = steam conducted through pipe, pounds per hour

d_p = pressure drop in pipe, pounds per square inch

d = inside diameter of pipe, inches

w = density of steam, pounds per cubic foot

L = length of pipe over which pressure drop is noted, feet

Solution:

$$W_{fs} = \frac{5(1.12)^6 2}{360(100)\ (1.12 + 3.6)}$$

$$= .0108 \text{ pounds per hour}$$

Flow Rate of Water:

Formula:

$$F_g = 4.32 \frac{P_d d^2}{fL}$$

$$F_w = .0096 \frac{P_d d^5}{fL}$$

Where: F_g = fluid flow rate, gallons per minute

F_w = fluid flow rate, cubic feet per second

P_d = pressure drop in pipe, pounds per square inch

d = inside diameter of pipe, inches

f = friction factor obtained from manufacturer of pipe, usually between 0.001 and 1.0

L = length of pipe over which pressure drop is noted, feet

APPENDIX C

EXHIBITS

SAMPLE MAINTENANCE CHECK LISTS

TABLE OF CONTENTS

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Window A/C Unit		
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
SAFETY	1	Comply with all safety procedures. Disconnect unit while performing maintenance except when operation is required.						X
	2	Check frame of unit with ohmmeter for proper electric ground.						X
PRIOR TO COOLING SEASON	1	Check general condition of unit. Look for loose or broken fasteners, control switches, knobs, defective wiring, or plug(s). Check for damaged or cracked tubing. Remove dust or dirt from interior parts.						X
	2	Check condition of coils. Look for damage or dirt. If required, clean coils with water or blow out with air. Inspect gaskets. Look for leaks between unit and window caulk as necessary.						X
	3	Check drain holes or tubes, if installed.						X
	4	Check fan blades for damage or dirt. Check set-screw fastener. Clean blades, if required.						X
	5	Check general condition of motor and check for free rotation.						X
	6	Check filters; clean or replace, if necessary.						X
	7	Operate unit in all modes. Check for proper function, smooth control, and damper movement.						X
AFTER COOLING SEASON	1	Check general condition of unit. Look for loose or broken fasteners, control switches, knobs, defective wiring or plug(s). Check for damaged or cracked tubing.						X
	2	Check condition of coils. Clean with water or blow out with air.						X
	3	Clean bottom frame of unit. Check drain holes or tubes, if installed.						X
	4	Check fan blades for damage. Clean blades. Check setscrew fastener.						X

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EXHIBIT 2-1

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION										
WORK CODE		EQUIP. ACRONYM					NUMBER			TYPE
0	3	H	V	A	C					

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Window A/C Unit		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
AFTER COOLING SEASON (continued)	5	Check motor for condition and for free rotation. Consult manufacturer's instructions. Lubricate, if required.						X
	6	Clean or replace filters.						X
	7	Operate unit in all modes. Check for proper function and smooth control movement.						X
	8	If unit is exposed to weather, install cover on weather side, if available.						X

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EXHIBIT 2-1 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Package A/C Unit		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	-

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
SAFETY		Shut down equipment. Lock out disconnect switch. Observe appropriate safety precautions.		X	X	X	X	X
FAN SECTION	1	Check fan for free rotation and debris. Clean, if required.		X	X	X	X	X
	2	Check fan bearings, lubricate if required.					X	X
	3	Check pulleys for tightness/alignment.					X	X
	4	Check belts for proper tension/wear. Adjust or replace, if required.					X	X
	5	Check fan motor mounting bolts and vibration eliminators for tightness.					X	X
COMPRESSOR SECTION	1	Check for oil leaks and proper oil level.		X	X	X	X	X
	2	Check vibration mounts.					X	X
	3	With unit running, check for unusual vibration.		X	X	X	X	X
	4	Check cutout switch settings.					X	X
	5	Check wiring and refrigerant lines for chaffing, damage, and leaks.					X	X
ELECTRICAL PANEL	1	Check fuses for loose connections.					X	X
	2	With unit running, check amp draw on components.						X
	3	Check relay contacts.						X
FILTER	1	Check filter condition. Replace, if necessary.		X	X	X	X	X
	2	Check filter switch.		X	X	X	X	X
STRUCTURE	1	Check structure and panels for insulation damage, missing fasteners, gaskets and leaks. Clean interior/exterior as required.					X	X

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EXHIBIT 2-2

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION									
WORK CODE		EQUIP. ACRONYM				NUMBER			TYPE
0	3	H	V	A	C				

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Package A/C Unit		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
EVAPORATOR SECTION	1	With unit running, check suction pressure, head pressure, refrigerant charge (sight glass) Check temperature differential across section.					X	X
	2	Clean evaporator coil. Check for insulation damage.					X	X
	3	Check refrigerant lines and fittings for tightness and chaffing.					X	X
CONTROLS	1	Clean sensor bulb(s).					X	X
	2	Clean internal panel.					X	X
	3	With unit running, check for fast cycling on compressor(s).		X	X	X	X	X
HUMIDIFIER	1	Check calibration of humidity control.						X
	2	Drain and clean pan.		X	X	X	X	X
	3	Check and clean float valve.		X	X	X	X	X
	4	Check for burnt out elements or lamps.		X	X	X	X	X
REHEAT SECTION (ELECTRIC)	1	Check fuses.		X	X	X	X	X
	2	Check heater elements.					X	X
	3	Check safety switch.					X	X
	4	Check wiring.						X
REHEAT SECTION STEAM/HOT WATER	1	Check valves and piping for leakage.					X	X
	2	Clean fins on reheat coil, if required.					X	X
WATER-COOLED CONDENSER	1	Check unit for leaks.		X	X	X	X	X

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EXHIBIT 2-2 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION							
WORK CODE		EQUIP. ACRONYM				NUMBER	TYPE
0	3	H	V	A	C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Package A/C Unit		
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
GLYCOL HEAT EXCHANGER	1	Check motor for excessive heat, noise, and vibration. Check mounting bolts for tightness. Clean motor.				X	X	
	2	Check fan blades for clearance, set screw tightness. Clean as needed.					X	X
	3	Check unit housing for loose screws, nuts, and bolts. Clean as required.					X	X
	4	Check coils for leaks and foreign material. Clean with high pressure water or air if required.			X	X	X	X
	5	Check for loose conduit.					X	X
	6	Check pump motor for excessive noise, heat, vibration or leaks. Lubricate if required.		X	X	X	X	X

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EXHIBIT 2-2 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning/Heating	Heat Pump		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24	-

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
SAFETY	1	Shut down equipment. Lock out disconnect. Observe appropriate safety precautions.				X	X	X
OUTDOOR COIL	1	Check outdoor coil for damage. Look for chafing lines and dirt buildup.					X	X
	2	Flush outdoor coil with water hose, if necessary. Remove debris and scale, if present.					X	X
	3	Clean and inspect defrost sensors (if equipped).					X	X
OUTDOOR FAN	1	Check fan for free rotation and debris. Clean, if required.					X	X
	2	Check fan bearings for play. Consult manufacturer's recommendation. Lubricate, if required.					X	X
	3	Check fan motor mounting bolts and vibration eliminators for tightness.					X	X
COMPRESSOR SECTION	1	Check for oil leaks and proper oil level.					X	X
	2	Check vibration mounts.					X	X
	3	With unit running, check for unusual vibration.					X	X
	4	Check cutout switch settings.					X	X
	5	Check wiring and refrigerant lines for chaffing, damage, and leaks.					X	X
ELECTRICAL PANEL	1	Check fuses for loose connections.					X	X
	2	With unit running, check amp draw on components.					X	X
	3	Check relay contacts.					X	X
STRUCTURE	1	Check structure and panels for insulation damage, missing fasteners, gaskets, and leaks. Clean interior/exterior as required.					X	X
	2	Inspect drain holes in compartment base. Clean, if necessary.					X	X

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EXHIBIT 2-3

U.S. POSTAL SERVICE MAINTENANCE CHECK LIST	IDENTIFICATION: WORK CODE 0 3 · EQUIP. ACRONYM H V A C · NUMBER · TYPE

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning/Heating	Heat Pump		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	B	M	C	Q	S	A
INDOOR COIL	1	Clean coil, if necessary.					X	X
	2	Check connecting lines, joints, and coil for evidence of oil leaks.					X	X
	3	Check condensate line. Clean, if necessary.					X	X
INDOOR FAN	1	Clean or change filters.				X	X	X
	2	Check blower for free rotation and debris. Clean, if required.					X	X
	3	Check fan bearings. Consult manufacturer's recommendations. Lubricate, if required.					X	X
CONTROLS	1	Check thermostat and mode switch for operation and damage.					X	X
	2	Cycle unit through different operating modes.					X	X

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EXHIBIT 2-3 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Heating			
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
Gas Forced-Air Furnace			

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
SAFETY	1	Comply with all safety precautions.							X
	2	Check operation of safety pilot gas shut off valve and other burner safety devices.							X
BLOWER	1	Disconnect furnace, lockout and tag.							X
	2	Check fan for tightness on motor shaft. Clean fan unit and motor.							X
	3	Consult manufacture's specifications. Lube motor as required.							X
	4	With unit running, check operation of fan limit control for proper start and stop temperatures.							X
FILTERS	1	Clean or replace filters as required.							X
	2	Vacuum interior of filter compartment.							X
FLUE AND CHIMNEY	1	Check flue pipe, draft diverter, and chimney for connection tightness and rust or damage. Ensure there is no blockage.							X
	2	With unit running, check for proper draft.							X
	3	If unit equipped with automatic flue damper, inspect and check for proper operation.							X
BURNERS	1	Disconnect, furnace lockout and tag power and gas supply.							X
	2	Remove burners, inspect for any damage. Clean burners, pilot and thermocouple with wire brush. Clean all burner and pilot orifaces.							X
	3	Reinstall burners. Turn on gas and power.							X
	4	Check pilot flame. Flame should be soft blue. Flame should surround the end of the flame sensor. Adjust if required.							X
	5	If electric ignition equipped, check electrode gap and operation.							X

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EXHIBIT 2-4

U.S. POSTAL SERVICE
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IDENTIFICATION											
WORK CODE		EQUIP. ACRONYM						NUMBER			TYPE
0	3	H	V	A	C						

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Heating			
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
Gas Forced-Air Furnace			

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
BURNERS (Continued)	6	Check burner flame. Allow burner to operate for several minutes to establish a normal burning condition. Observe burner flame, it should be mainly blue in color, strong in appearance, and rise directly from the burner parts into the heat exchanger. Check that flame is burning from all parts and does not impinge on sides of heat exchanger.							X
HEAT EXCHANGER	1	Turn off electric and gas supply to furnace.							X
	2	Remove access panels. Inspect heat exchanger for damage and dirt. Clean if required.							X

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EXHIBIT 2-4 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION										
WORK CODE		EQUIP. ACRONYM				NUMBER				TYPE
0	3	H	V	A	C					

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Heating	Oil-Fired Boiler		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
Cast-Iron/Fire-Tube Boiler		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
SAFETY	1	Observe appropriate safety precautions.							X
	2	Check operation of flame detector and aquastats.							X
	3	Disconnect boiler, lockout and tag oil and electrical supplys.							X
FLUE AND CHIMNEY	1	Check flue pipe and chimney for connection tightness and rust and damage. Ensure there is no blockage.							X
	2	Check operation of flue damper. Ensure damper moves freely.							X
BURNER	1	Remove burner from boiler.							X
	2	Replace burner nozzle and oil filter.							X
	3	Check or adjust electrode setting on burner. Inspect insulators.							X
	4	Check blower for tightness on motor. Clean blower blades to remove dirt buildup.							X
	5	Check coupling between motor and fuel unit for tightness.							X
	6	Check fuel unit for leaks or damaged tubing.							X
	7	Check wiring to ignition transformer and burner control unit. Look for damaged or frayed wires.							X
	8	Consult manufacturer's instructions. Lubricate blower motor if required.							X
HEAT EXCHANGER	1	Remove access panels. Clean heat exchanger with brush and vacuum to remove soot.							X
	2	Inspect heat exchange for cracks and damage.							X

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EXHIBIT 2-5

U.S. POSTAL SERVICE
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IDENTIFICATION								
WORK CODE		EQUIP. ACRONYM					NUMBER	TYPE
0	3	H	V	A	C			

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Heating	Oil-Fired Boiler		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
Cast-Iron/Fire-Tube Boiler		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
COMBUSTION CHAMBER	1	Vacuum soot from combustion chamber.							X
	2	Inspect combustion chamber for cracks and damage. Seal any air leakage points in the combustion chamber.							X
CIRCULATOR PUMP & PIPING	1	Inspect circulator pump. Check for smooth operation. Look for defective or damaged wiring.							X
	2	Check piping. Look for damaged or leaking pipe and valve connections.							X
	3	Inspect expansion tank for leaks or damage.							X
	4	Consult manufacturer's instructions. Lubricate circulator pump, if required.							X
GENERAL	1	Reassemble boiler. Clean exterior cabinet. Turn on power.							X
PERFORMANCE ADJUSTMENT	1	Allow boiler to run for 10 minutes to warm up.							X
	2	Check draft reading over fire. Adjust draft regulator on flue to give draft recommended by manufacturer. If recommendation not available, set for 0.02" water column.							X
	3	Check smoke readings.							X
	4	Adjust for several different air settings; run burner at each setting. Record smoke and CO_2 levels from flue on chart. See MS-24, Chapter 2, Figure 2-15.							X
	5	Examine Smoke-CO_2 Curve. Note where smoke begins to rise sharply. Adjust the air setting to a CO_2 level 1/2 to 1% lower than level at knee of curve.							X
	6	Ensure final adjustment results in smoke not greater than #1 and a CO_2 level not less than table shown on Smoke-CO_2 chart in MS-24, Chapter 2, Figure 2-15.							X

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SAMPLE

EXHIBIT 2-5 (Continued)

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IDENTIFICATION								
WORK CODE		EQUIP. ACRONYM				NUMBER		TYPE
0	3	H	V	A	C			

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Heating	Oil-Fired Boiler		
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)
Cast-Iron/Fire-Tube Boiler		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
PERFORMANCE ADJUSTMENT (Continued)	7	Operate lever on pressure-temperature relief valve. Water should flow freely and stop when lever is released. Replace valve, if it is defective.							X
	8	Check thermostats and controls for proper settings.							X

SAMPLE

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EXHIBIT 2-5 (Continued)

U.S. POSTAL SERVICE
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IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Hot Water	Water Heater Electric		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	W	M	B	Q	S	A
SAFETY	1	Comply with all safety precautions.						X
	2	Check operation of safety devices.						X
CIRCULATOR PUMP AND PIPING	1	Inspect circulator pump (if equipped). Check for smooth operation. Look for defective or damaged wiring.						X
	2	Check piping. Look for damaged or leaking pipe and valve connections.						X
	3	If equipped, consult manufacturer's instructions. Lube circulator pump if required.						X
ELECTRIC HEATING ELEMENTS	1	Check electric wiring for loose or damaged connections.						X
THERMOSTAT	1	Check thermostat operation. Set thermostat to deliver no warmer than 100°F water to lavatories and 180°F water to kitchens or cafeterias.						X
RELIEF VALVE	1	Operate try lever on pressure temperature relief valve. Water should flow freely and stop when try lever is released. Replace valve if defective.						X
STRUCTURE	1	Clean exterior of heater. Check for damage or defective insulation.						X

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EXHIBIT 2-6A

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
03	HVAC		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Domestic Hot Water	Water Heater Gas		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
SAFETY	1	Comply with all safety precautions.							X
	2	Check operation of safety pilot gas shutoff valve and other burner safety devices.							X
CIRCULATOR PUMP AND PIPING	1	Inspect circulator pump (if equipped). Check for smooth operation and leakage. Look for defective or damaged wiring.							X
	2	Check piping. Look for damaged or leaking pipe and valve connections.							X
	3	Consult manufacturer's instructions Lubricate circulator pump and motor as required.							X
BOTTOM DRAIN	1	Drain water from bottom drain bib till water stream runs clear.							X
BURNER	1	Disconnect Heater, lockout and tag gas supply and (electrical supply, if installed).							X
	2	Remove burners, inspect for overall damage. Clean burners, pilot and thermocouple with wire brush. Clean all burner and pilot orifices.							X
	3	If electric ignition equipped, check electrode gap and operation.							X
	4	Reinstall burners. Restore gas supply and and electricity.							X
	5	Check pilot flame. Flame should be soft blue. Flame should surround the end of the flame sensor. Adjust, if required.							X
	6	Check burner flame. Allow to operate for several minutes to establish normal burning condition. Check burner flame by observation. Flame should be predominately blue in color, strong in appearance, and rise directly from the burner parts into the heat exchanger. Check that flame is burning from all parts and does not impinge on sides of heat exchanger.							X

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EXHIBIT 2-6B

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION										
WORK CODE		EQUIP. ACRONYM						NUMBER		TYPE
0	3	H	V	A	C					

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Domestic Hot Water	Water Heater Gas		
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	B	Q	S	A
FLUE AND CHIMNEY	1	Check flue pipe and chimney for connection tightness and rust or damage. Ensure there is no blockage.							X
	2	With unit running, check for proper draft by holding lighted match or cigarette below vent hood. Observe smoke being drawn into flue.							X
THERMOSTAT	1	Check thermostat operation. Set thermostat to deliver no warmer than 100°F water to lavatories and 180°F water to kitchens or cafeterias.							X
RELIEF VALVE	1	Operate try lever on pressure-temperature relief valve. Water should flow freely and stop when try lever is released. Replace valve, if defective.							X
STRUCTURE	1	Clean exterior of heater. Check for damage or defective insulation.							X

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EXHIBIT 2-6B (Continued)

U.S. POSTAL SERVICE MAINTENANCE CHECK LIST	IDENTIFICATION: WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
	0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Ventilation	Wet-Type Air Cleaner		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY SERVICE FACTOR MOD	SEVERE
SAFETY	1	Observe appropriate safety precautions. Shut down unit.	Q	M
CABINET	1	With access panels removed, inspect cabinet interior for residue buildup, rust, and corrosion. Clean as necessary.	Q	M
BLOWER	1	Check blower for smooth rotation. Look for dirt buildup on blower blades. Clean, if required.	Q	M
	2	Check manufacturer's instructions. Lubricate motor and blower bearings if required.	Q	S
	3	Check blower V-belt(s) for wear and proper tension. Adjust if required.	Q	S
PIPING	1	Check supply and drain piping for leaks and damage.	Q	M
	2	Check nozzle(s) for cleanliness and proper spray pattern. Clean or replace as required.	Q	M
ELECTRIC CONTROLS	1	Inspect electric controls for proper operation and damage.	S	Q
	2	Inspect wiring for loose or damaged wiring.	S	Q
INLET DUCT	1	Check inlet duct for damage or air leaks. Clean inlet registers.	S	Q
GENERAL	1	Reassemble unit and test. Look for good air flow and smooth operation.	Q	M

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EXHIBIT 2-7

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
03	HVAC		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Ventilation	Media Air Cleaner		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	-

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY SERVICE FACTOR MOD			SEVERE
SAFETY	1	Observe appropriate safety precautions. Shut down unit.	Q			M
PREFILTERS	1	Remove, clean, or replace prefilters. Clean inlet register(s).	Q			M
MEDIA FILTERS	1	Remove media filter. Clean or replace in accordance with manufacturer's instructions.	Q			M
CABINET	1	With filter(s) removed, inspect cabinet for damage. Clean interior and exterior of cabinet.	Q			M
	2	Check controls for proper operation. Check for broken or damaged wiring.	Q			M
BLOWER	1	Check blower motor for smooth rotation. Look for dirt buildup on blower blades. Clean if required.	Q			M
	2	Check manufacturer's instructions. Lubricate motor and blower bearings if required.	A			S
	3	If equipped, check V-belt for wear and proper tension. Adjust if required.	S			Q
INLET DUCT	1	Check inlet duct for damage or air leaks.	Q			Q
SHAKER BAR AND HOPPER	1	If equipped, check operation of shaker bar and drive motor. Clean and lubricate as directed in manufacturer's instructions. Empty and clean hopper.	S			Q
GENERAL	1	Reassemble unit and test. Look for good air flow and smooth operation.	Q			M

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EXHIBIT 2-8

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION: WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Ventilation	Electrostatic Air Cleaner		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	-

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY SERVICE FACTOR MOD	SEVERE
SAFETY	1	Observe appropriate safety precautions. Shut down unit.	Q	M
	2	Wait 3 to 5 minutes for electrostatic charge to dissipate.	Q	M
PREFILTERS	1	Remove, clean, or replace prefilters. Clean inlet register(s).	Q	M
CELLS AND IONIZER	1	Remove and clean cells by rinsing with warm to hot water. Follow rinse by immersion in a warm commercial grade detergent solution at at temperature of 140 to 160 °F. Allow components to soak in solution 1-1/2 to 2 hours.	Q	M
	2	Remove cell from solution. Inspect for bent plates, damaged insulators, or broken wires.	Q	M
CABINET	1	With cell(s), ionizer(s), and prefilter(s) removed, inspect cabinet for damage. Clean interior and exterior of cabinet.	Q	M
	2	Check controls for proper operation. Check for broken or damaged wiring.	Q	M
BLOWER	1	Check blower motor for smooth rotation. Look for dirt buildup on blower blades. Clean if required.	S	Q
	2	Check manufacturers instructions. Lubricate motor and blower bearings, if required.	A	S
	3	If equipped, check V-belt for wear and proper tension.	S	Q
CHARCOAL ODOR FILTER	1	If equipped, replace charcoal odor filter.	S	Q
INLET DUCT	1	Check inlet duct for damage or air leaks.	Q	M
GENERAL	1	Reassemble unit and test. Look for good air flow and smooth operation. Listen for snapping sound indicating ionizer operation. If unit snaps continuously, check equipment troubleshooting guide.	Q	M

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EXHIBIT 2-9

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Refrig Machines (Centrifugal & Reciprocating)			
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY A
SAFETY	1	Comply with all current safety precautions. Disconnect power except when operations must be performed with equipment running.	X
SPECIAL INSTRUCTIONS	1	Open and tag electric circuits.	X
CHECKPOINTS	1	Compressor	
		a. Drain, flush, and change oil in reservoirs including filters, strainers, and traps. Do not change oil in reciprocating machines unless contaminated.	X
		b. Clean and inspect main, auxiliary oil pumps, including packing, seals, alignment, pulleys, belts, and couplings.	X
		c. Check speed increase; drain oil from gear box; flush and inspect gears for indication of wear, pitting, and alignment.	X
		d. Remove head from oil coolers, inspect and clean tubes. Change oil filters.	X
		e. Refill oil sump.	X
		f. Remove access caps to compressor internals and clean where possible.	X
		g. Clean and adjust pilot positioner for guide vanes.	X
		h. Examine bearing for clearances and wear.	X
		i. Clean and lubricate coupling.	X
		j. Check hot and cold alignment between drive and driven compressor.	X
		k. Check all relief valve rupture discs.	X
		l. Test entire system for refrigerant leaks.	X
		m. Calibrate and adjust all gauges and instruments. Note the thermometers that measure inlet and outlet temperature of chilled water should be calibrated together. This can be done by placing the sensing element in a container of melting ice and water. This will provide a temperature of 32 °F for calibration purposes.	X
		n. Check safety controls for setting and operation; tighten electrical connections and clean if needed.	X

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EXHIBIT 3-1

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION				
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Refrig Machines (Centrifugal & Reciprocating)			
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY A
CHECKPOINTS (continued)		o. Review manufacturer's literature for further details on service required on compressor.	X
		p. Perform maintenance on purge unit in accordance with manufacturer's instructions.	X
		q. Leave equipment and area clean and free of debris.	X
	2	Evaporator	
		a. Note chiller performance on log sheets (inlet and outlet chilled water temperature and refrigerant temperatures).	X
		b. If efficiency is reduced, inspect for control malfunction or sensing element failure.	X
		c. Systems requiring minimum or no raw water makeup should be drained and inspected only in emergencies. pH should be maintained between 0.7 and 0.8. To determine that system is tight, disconnect automatic makeup water system and feed by hand. Frequency for cleaning on such systems should be once in every 5 years.	X
		d. Clean tubes with nylon brush or brush made of similar material.	X
		e. Blow tubes free of trapped water, if unit is to be exposed to freezing temperatures.	X
		f. Replace heads, installing new gaskets.	X
		g. Treat water to control corrosion.	X
	3	Water-cooled condensers	
		a. Review log and note condenser performance by inlet and outlet temperatures, head pressure, and temperature of refrigerant.	X
		b. Remove condenser heads.	X
		c. Remove mud, debris, scale, and other sediment collected during operation.	X
		d. Clean water boxes and tube sheets. Scrape and paint with epoxy.	X
		e. Clean tubes with nylon brush or brush made of similar material and inspect for signs of corrosion.	X

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EXHIBIT 3-1 (Continued)

U.S. POSTAL SERVICE MAINTENANCE CHECK LIST	IDENTIFICATION								
	WORK CODE		EQUIP. ACRONYM					NUMBER	TYPE
	0	3	H	V	A	C			

SYSTEM/LOCATION Refrig Machines (Centrifugal & Reciprocating)	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY A
CHECKPOINTS (continued)		f. Blow trapped water from tubes after cleaning, if unit is exposed to freezing temperature.	X
		g. Replace heads, installing new gaskets.	X
		h. Chemically test scale, if necessary.	X
		i. If condenser is chemically cleaned, neutralize after cleaning.	X

SAMPLE

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PAGE 3 OF 3 PAGES

EXHIBIT 3-1 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Refrig Mach Room		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY T	D	W
SAFETY	1	Comply with all current safety precautions.			X
REFRIGERATION MACHINE	1	While machine is running, check for leaks indicated by: a. Higher than normal purge discharge gauge pressure. b. Purge relief valve discharging to atmosphere. c. Water accumulation in the upper bull's-eye of the purge separator machine. Any water accumulation should be removed.			X
	2	Clean strainer on condenser water line to cooler.			X
	3	Clean water side of oil cooler.			X
	4	Record data on Form 4990 and observe oil level in bull's-eye. Add oil if needed (York Freon Compressor Oil "B", Part No. 11-309). Observe any visible changes in equipment appearance, such as oil spots on connections or floor under equipment. Also notice unusual noise of machine operation.	X		
	5 *	Check pressure in machine by use of temperature pressure chart while machine is off.		X	
PUMPS	1	Check pumps for suction and discharge pressures. Also check motor and pump bearings by feel for overheating.			X
	2	Check and adjust packing glands. (WATER should drip slowly from packing gland, about one drop every 2 seconds when pump is off.) Keep adjusting bolts and nuts clean and lubricated. NOTE: Pumps with mechanical seals need no adjusting.			X
	3	Check mechanical seals on pumps for leaks while machine is off.	X		

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EXHIBIT 3-2

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air-Conditioning	Refrig Mach Room		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY T	D	W				
PNEUMATIC AIR COMPRESSOR FOR CONTROLS	1	Check air compressor oil level. If low, add oil. Johnson's DL-23 oil.			X				
	2	Check belt tension and alignment.			X				
	3	Drain condensate from air compressor tanks.	X						
	4 #	Check air pressure in supply tank and the pressure adjustment in the supply line for proper limits.		X					
	5 *	Treat the condenser water and chilled water. Frequency: As directed by water laboratory technicians.		X					
		* NOTE: During air conditioning season only (April 15 to October 15)							
		# NOTE: All year							

SAMPLE

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PAGE 2 OF 2 PAGES

EXHIBIT 3-2 (Continued)

OPERATING LOG FOR RECIPROCATING TYPE REFRIGERATION MACHINES

(Cooling Season)

BUILDING | MONTH AND YEAR

MACHINE NUMBER AND DATE	TIME CHECKED	OUTSIDE CONDITIONS				COMPRESSOR									CONDENSER		CHILLER	
		TEMPERATURES		SUNSHINE (Check one)		HIGH SIDE HEAD		LOW SIDE SUCTION		OIL GEAR BOX					WATER TEMPERATURE		WATER TEMPERATURE	
		D.B.	W.B.	YES	NO	PRESSURE	TEMPERATURE	PRESSURE	TEMPERATURE	PRESSURE	TEMPERATURE				IN	OUT	IN	OUT
(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
	___ A.M.																	
	___ A.M.																	
___ (No.)	___ P.M.																	
	___ P.M.																	
___ (Date)	___ P.M.																	
	___ P.M.																	
	___ A.M.																	
	___ A.M.																	
___ (No.)	___ P.M.																	
	___ P.M.																	
___ (Date)	___ P.M.																	
	___ P.M.																	
	___ A.M.																	
	___ A.M.																	
___ (No.)	___ P.M.																	
	___ P.M.																	
___ (Date)	___ P.M.																	
	___ P.M.																	
	___ A.M.																	
	___ A.M.																	
___ (No.)	___ P.M.																	
	___ P.M.																	
___ (Date)	___ P.M.																	
	___ P.M.																	

INSTRUCTIONS

GENERAL—Where 1 machine is installed, use the form to cover 4 days operation; where 2 machines are installed, use the form to cover 2 days operation; and, where 3 or 4 machines, use to cover each day of operation.

COLUMN (1)—Show the number of the machine in operation and the date. If machine is not in operation, so indicate.

COLUMN (2)—Readings are to be taken at the end and middle of each tour.

COLUMN (11)—Applies to open units only where they have gear box.

COMMENTS—Use reverse for comments or notes deemed necessary or of interest.

PS Form 4990
June 1971

EXHIBIT 3-3

U.S. POSTAL SERVICE

OPERATING LOG FOR CENTRIFUGAL REFRIGERATION PLANTS

Building (City and Date)	Design Wet Bulb	Reviewed by (Name, Title and Date)

Hour	Machine Number	Outside Weather Conditions			Evaporator GPM______(4)					Condenser GPM______(5)				Compressor							Purge			Efficiency		
		Temperatures		% Sunshine or Condition	Suct. Pressure (Hg or PSIG)	Liquid Temp. (F)	Liquid Level	Chilled Water Temp.		Disch. Pressure	Cond. Temp (F)	Condenser Water Temp.		Capacity Indicator Position	Bearing Temp.		Oil			Motor Amperes	Automatic Purge Units			Compressor		AMPS Per Ton
															Main (F)	Motor End (F)	Level	Temp. (F)	Press. (PSIG)		Suct.	Disch.	Oil Level	Act Tons Ref.	% Mach. Cap.	
(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)

Tour 1	Tour 2	Tour 3
Name and Title	Name and Title	Name and Title
Remarks (33)	Remarks (33)	Remarks (33)

Meters (Midnight Reading)

Building Electric Meters

	No. 1	No. 2	No. 3
Fin.			
Start			
Diff.			

Compressor KW (35)

	No. 1	No. 2	No. 3
Fins.			
Start			
Diff.			

Cooling Tower Make-up (36)

Fin.	
Start	
Diff.	

PS Form 4994, Jan. 1983

(See Instructions On Reverse)

EXHIBIT 3-4

ABSORPTION OPERATION LOG

UNIT DESIGNATION ______________________ UNIT SERIAL NO. __________ DATE __________

OPERATOR ______________________ TIME STARTED __________ AM ___ PM ___

STATION NO.	LOCATION	1	2	3	4	5	6	7	8
	STEAM PRESSURE INLET PSIG								
	HOT WATER IN CONCENTRATOR °F								
	HOT WATER OUT CONCENTRATOR °F								
	CHILLED WATER INLET - °F								
	CHILLED WATER OUTLET - °F								
	CHILLED WATER PRES. DIFF.- PSIG								
	CONDENSOR WATER ABS. INLET -°F								
	CONDENSER WATER ABS. OUTLET - °F								
	CONDENSER WATER COND. OUTLET - °F								
	ABSORBER-CONDENSER WATER TOTAL PRES. DIFF - PSIG								
	SOLUTION LEVEL								
	VOLTAGE								
	UNIT PUMPS - AMPS								

OPERATORS REPORT

ENTER ALL STARTS-STOPS-PERIODIC MAINTENANCE CHECKS, MALFUNCTIONS, ETC.

PERIODIC MAINTENANCE CHECKS

WEEKLY:

_____ RUN PURGE AS NEEDED

_____ CHECK VACUUM PUMP OIL

QUARTERLY:

_____ CLEAN STRAINERS IN PUMP LUBRICATING & COOLING CIRCUIT

_____ CLEAN STRAINERS IN STEAM (HOT WATER) CONDENSER & CHILLED WATER LINES.

REFER TO YOUR TRANE OPERATION & MAINTENANCE MANUAL FOR COMPLETE RECOMMENDATIONS AND PROCEDURES

EXHIBIT 3-5

ABSORPTION REFRIGERATION LOG

JOB NAME________________ JOB NO.__________ MACHINE SER. NO.__________ SIZE________

	COOLER					CONDENSING WATER					GENERATOR										
		WATERTEMP				ABSORBER			CONDENSER												
TIME	ABSOLUTE PRESSURE	IN	OUT	CHILLED WATER GPM	TONS	TEMP. IN	TEMP. OUT	GPM	TEMP. OUT	TEMP. TO TOWER	STRONG SOLUTION TEMP.	STEAM PRESSURE	VAPOR COND. TEMP.	EVAPORATOR WATER OVERFLOW	CAPACITY CONTROL VALVE POSITION	SOLUTION LEVEL IN ABSORBER	PURGE TANK LEVEL	EVAPORATOR WATER TEMPERATURE	WEAK SOLUTION TEMPERATURE	WEAK SOLUTION SPECIFIC GRAVITY	WEAK SOLUTION SAMPLE TEMPERATURE
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

RECLAIM EVAPORATOR WATER	ADD OCTYL ALCOHOL	DILUTION TIME	PURGE METERING	
			RATE______INCHES/MIN	DATE__________
DATE__________	DATE__________	DATE______ MINUTES______	DATE__________	ENGINEER__________

EXHIBIT 3-6

ETHYLENE GLYCOL
SPECIFIC GRAVITY

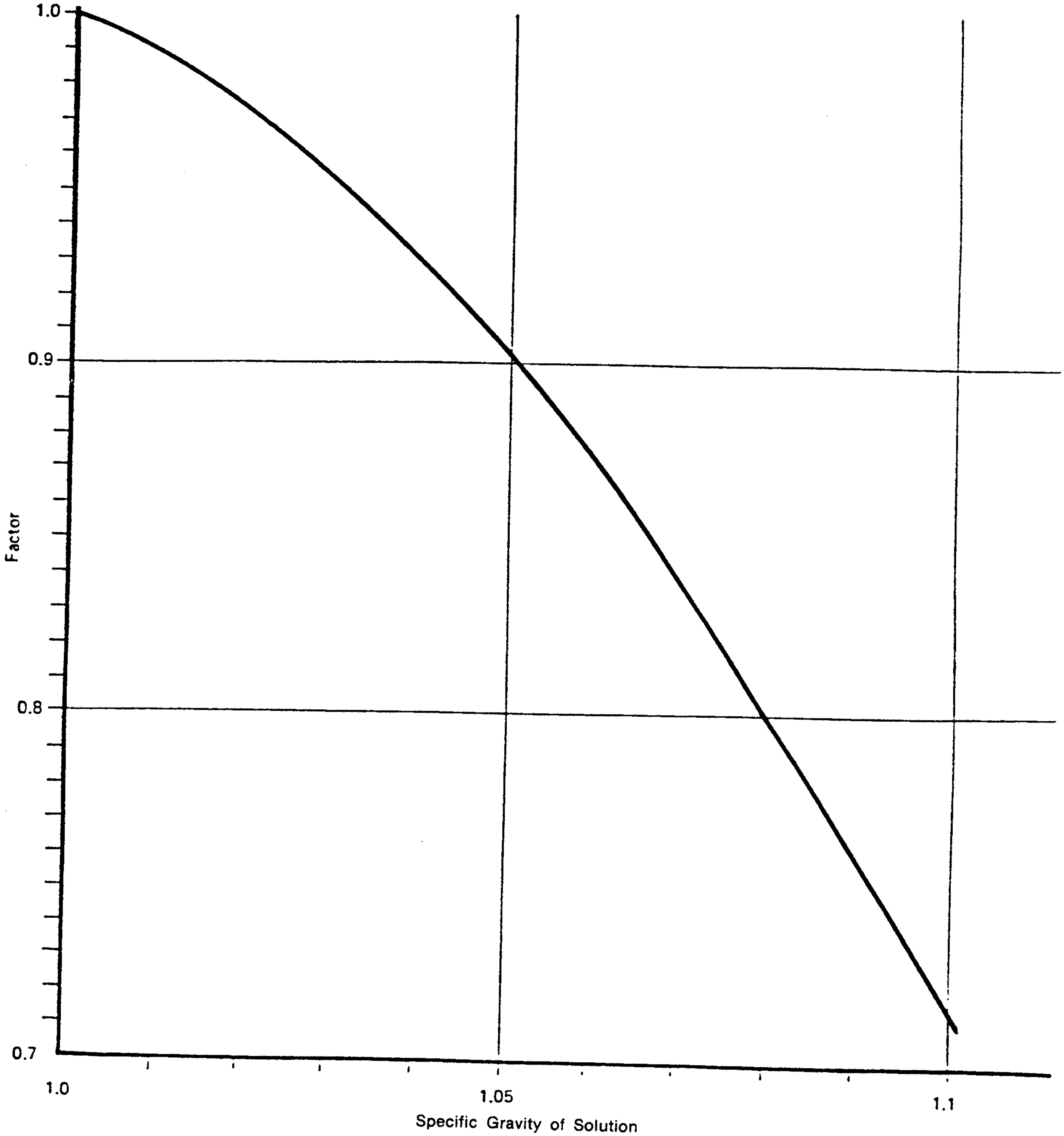

EXHIBIT 4-1

ETHYLENE GLYCOL
PERCENT

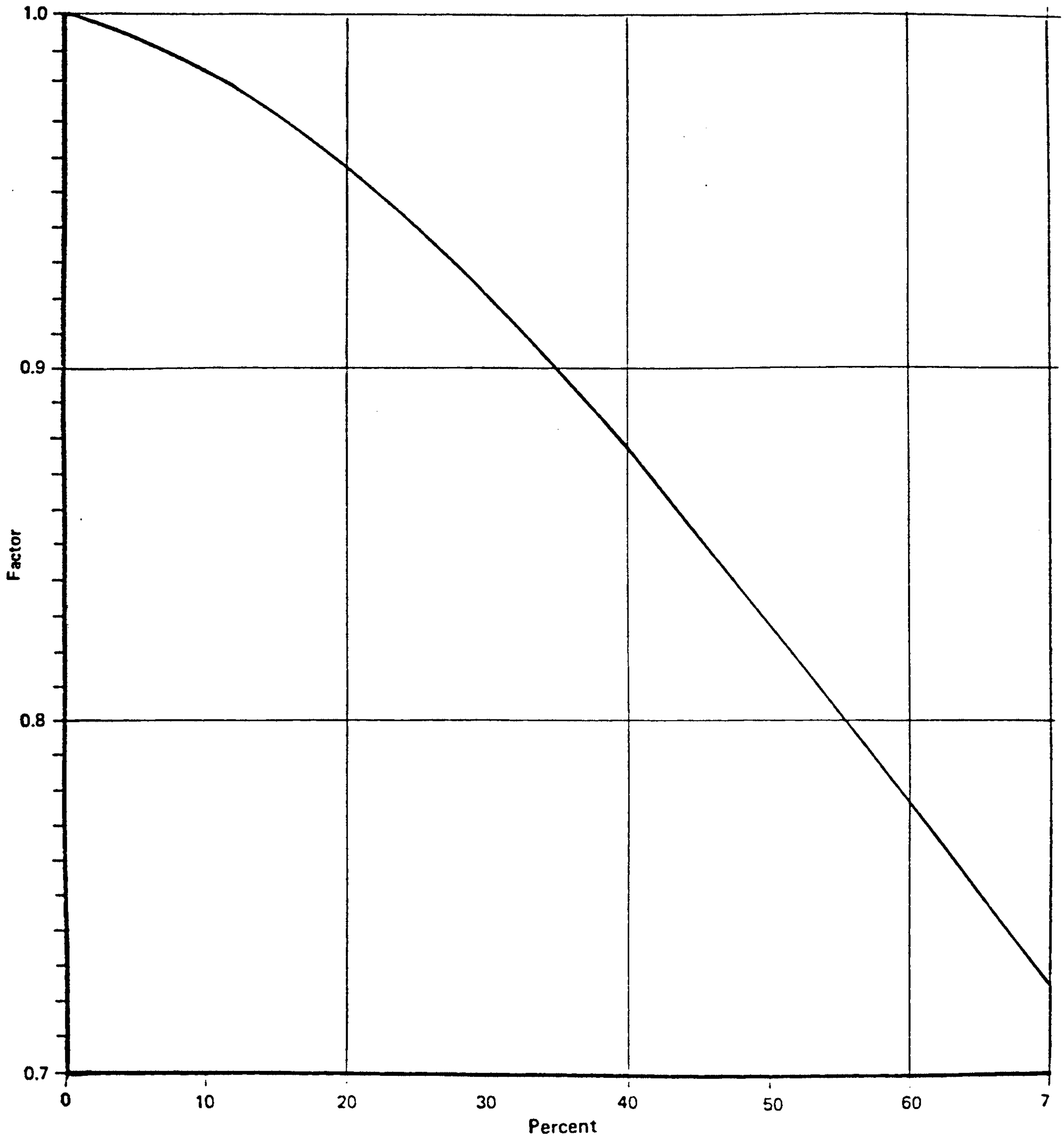

EXHIBIT 4-2

U.S. POSTAL SERVICE
LOW PRESSURE HEATING BOILER OPERATING LOG (HOT WATER)

BUILDING:		MONTH:	YEAR:
ADDRESS:		FUEL TYPE:	
PERSON(S) TO BE NOTIFIED IN EMERGENCY (NAME & TELEPHONE NO.)		BOILER NO.:	

Daily Checks

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1) RECORD PRESSURE	1ST READING																															
	2ND READING																															
2) RECORD BOILER WATER TEMP	1ST READING																															
	2ND READING																															
3) RECORD FLUE GAS TEMP	1ST READING																															
	2ND READING																															
4) OPERATOR'S INITIALS	1ST READING																															
	2ND READING																															

Weekly Checks (Enter Date)

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
1) OBSERVE FLAME CONDITION				
2) TEST LOW WATER CUT-OFF				
3) OBSERVE CIRCULATING PUMPS				

Monthly Checks (Enter Date)

1) MANUAL LIFT SAFETY RELIEF VALVE				
2) REVIEW CONDITION OF OR TEST EACH ITEM	A. FLAME DETECTION DEVICES		F. REFRACTORY	
	B. LIMIT CONTROLS		G. STOP VALVES	
	C. OPERATING CONTROLS		H. CHECK VALVES	
	D. FLOOR DRAINS		I. DRAIN VALVES	
	E. FUEL PIPING		J. LINKAGES	
3) OBSERVE GAGE GLASS ON EXPANSION TANK				
4) COMBUSTION AIR ADEQUATE/UNOBSTRUCTED				

GENERAL COMMENTS:

PS Form 4846-A, March 1985 (INSTRUCTIONS ON REVERSE)

EXHIBIT 5-1

U.S. POSTAL SERVICE
LOW PRESSURE HEATING BOILER OPERATING LOG (STEAM)

BUILDING:		MONTH:	YEAR:
ADDRESS:		FUEL TYPE:	
PERSON(S) TO BE NOTIFIED IN EMERGENCY (NAME & TELEPHONE NO.)		BOILER NO.:	

Daily Checks

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1) RECORD PRESSURE	1ST READING																															
	2ND READING																															
2) OBSERVE WATER LEVEL	1ST READING																															
	2ND READING																															
3) RECORD FLUE GAS TEMP	1ST READING																															
	2ND READING																															
4) OPERATOR'S INITIALS	1ST READING																															
	2ND READING																															

Weekly Checks (Enter Date)

	WEEK 1	WEEK 2	WEEK 3	WEEK 4
1) OBSERVE FLAME CONDITION				
2) TEST LOW WATER CUT-OFF				
3) TEST GAGE GLASS				

Monthly Checks (Enter Date)

1) MANUAL LIFT SAFETY VALVE				
2) REVIEW CONDITION OF OR TEST EACH ITEM	A. LINKAGES		F. FLOOR DRAINS	
	B. DAMPER CONTROLS		G. FLAME DETECTION DEVICE	
	C. STOP VALVES		H. LIMIT CONTROLS	
	D. REFRACTORY		I. OPERATING CONTROLS	
	E. FLUE-CHIMNEY BREECHING		J.	
3) INSPECT FUEL PIPING				
4) COMBUSTION AIR ADEQUATE/UNOBSTRUCTED				

GENERAL COMMENTS:

PS Form 4846, March 1985 (INSTRUCTIONS ON REVERSE)

EXHIBIT 5-2

MAINTENANCE, TESTING, AND INSPECTION LOG
HEATING BOILERS

YEAR________
CITY OR DIVISION________ BLDG.________
BOILER NO________ GAS ( ) OIL ( ) STEAM ( ) WATER ( )

	ROUTINE TO BE PERFORMED	FREQ	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	
1	OBSERVE PRESSURE & WATER LEVEL OR TEMP.														1
2	REPORT UNUSUAL NOISES OR CONDITIONS	D													2
3															3
4	OBSERVE CONDITION OF FLAME, REPORT IF	W													4
5	SMOKEY OR BURNER STARTS WITH PUFF														5
6															6
7	TEST LOW WATER FUEL CUT-OFF & WATER FEEDER	W													7
8	TEST GAUGE GLASS OR WATER COLUMN	W													8
9															9
10	OBSERVE CONDENSATE OR CIRCULATING PUMPS	W													10
11															11
12															12
13	CHECK CONDITION OF HEATING SURFACES	SA													13
14															14
15	TRY LEVER TEST - SAFETY OR RELIEF VALVE	M													15
16	TEST FLAME DETECTION DEVICES	M													16
17	TEST LIMIT CONTROLS	M													17
18	TEST OPERATING CONTROLS	M													18
19	INSPECT BOILER ROOM FLOOR DRAINS	M													19
20	INSPECT FUEL SUPPLY SYSTEM IN BOILER ROOM	M													20
21															21
22	SLUDGE BLOWDOWN	Q													22
23															23
24															24
25	COMBUSTION EFFICIENCY AND DRAFT TESTS	A													25
26															26
27	INTERNAL AND OR EXTERNAL INSP. AND CLEANING	A													27
28	ROUTINE BURNER	A													28
29	ROUTINE LOW WATER FUEL CUT-OFF	A													29
30	BLOWDOWN TEST - LOW WATER FUEL CUT-OFF	A													30
31	POP TEST - SAFETY OR RELIEF VALVE	A													31
32	ROUTINE CONDENSATE OR VACUUM PUMP	A													32
33	ROUTINE ENTIRE CONTROL SYSTEM	A													33
34	INSPECT BOILER ROOM AIR INTAKE	A													34
35	INSPECT GAS PIPING	A													35
36															36
37															37
38															38

D - DAILY W - WEEKLY M - MONTHLY Q - QUARTERLY SA - SEMI-ANNUALLY A - ANNUALLY AD - AS DIRECTED

EXHIBIT 5-3

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION									
WORK CODE		EQUIP. ACRONYM				NUMBER			TYPE
0	3	H	V	A	C				

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Boiler Room	Heating Boiler		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	-

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	D	W	M	Q	S	A
SAFETY	1	Report unusual noises and conditions.	X					X
BURNER	1	Conduct combustion efficiency and draft tests.						X
	2	Observe condition of flame; report if flame is smoky or burner starts with a puff or backfire.		X				
	3	Inspect fuel supply lines and valves.	X					
	4	Read and record pressures and temperatures.	X					
	5	Observe circulating pumps for proper operation.		X				
CONTROLS	1	Test low-water cutoff.		X				
	2	Test gauge glass or water column.		X				
	3	Check condensate or circulators.		X				
	4	Test levers on safety and relief valves.			X			
	5	Test flame detection devices.			X			
	6	Test operating controls.			X			
	7	Check emergency switch.			X			
	8	Inspect drain in boiler room.			X			
	9	Inspect fuel supply system in boiler room and tanks for leakage.		X				
	10	Conduct water-treatment test.			X			
BLOWDOWN	1	Check for sludge and check the blowdown system.				X		
	2	Check condition of heating surface.					X	

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EXHIBIT 5-4

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION										
WORK CODE		EQUIP. ACRONYM					NUMBER			TYPE
0	3	H	V	A	C					

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Boiler Room	Heating Boiler		
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**
		MS24MS1	

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY D	W	M	Q	S	A
SYSTEMS	1	Clean boiler internally and externally.						X
	2	Inspect and clean burner.						X
	3	Check low-water cutoff and fuel cutoff.						X
	4	Conduct blowdown drain test.						X
	5	Conduct pop test--safety or relief valve.						X
	6	Check condensate or vacuum pump.						X
	7	Test entire control system.						X
	8	Clean boiler room air intake.						X
	9	Check water treatment.					X	

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EXHIBIT 5-4 (Continued)

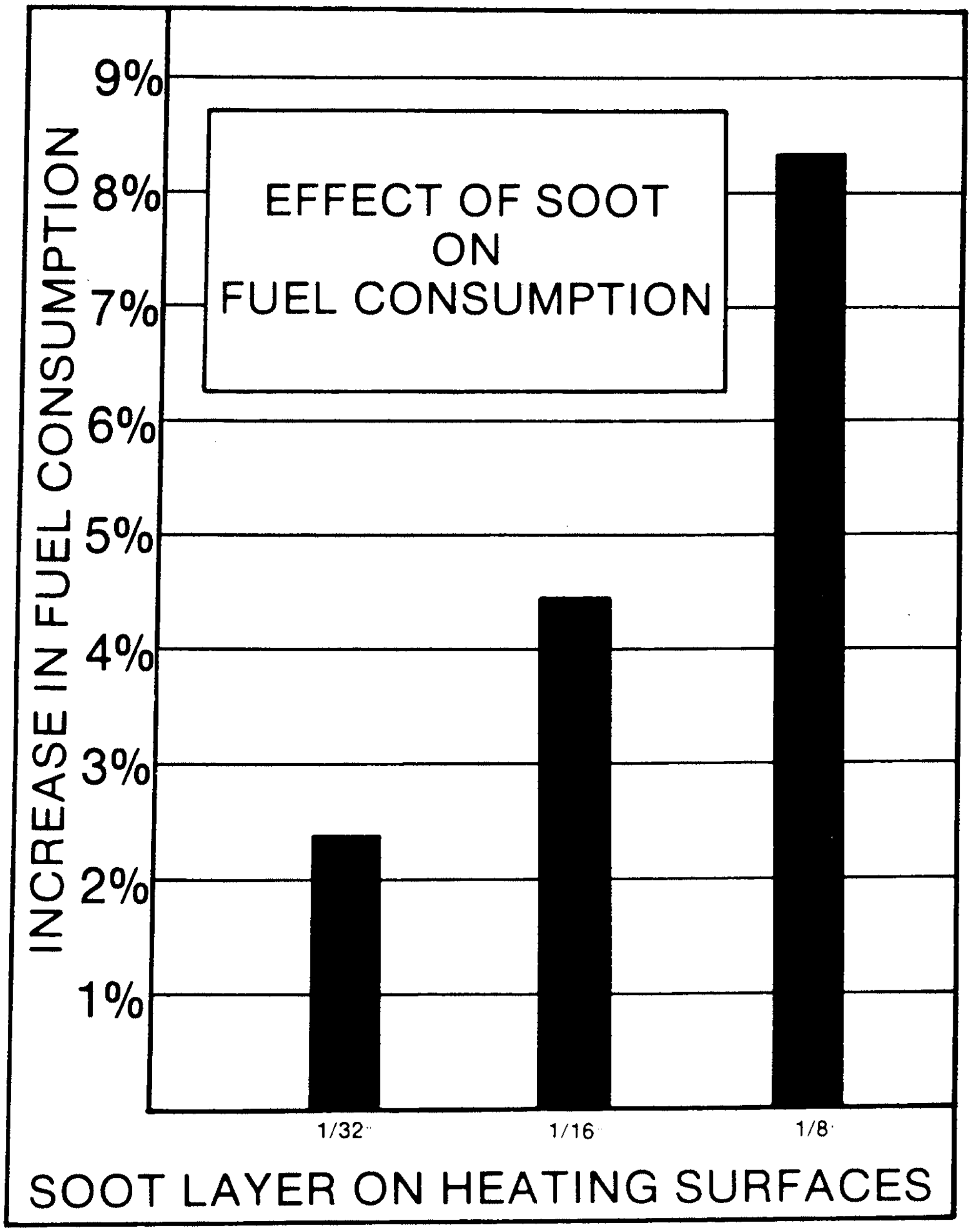
EFFECT OF SOOT
ON
FUEL CONSUMPTION
INCREASE IN FUEL CONSUMPTION
9%
8%
7%
6%
5%
4%
3%
2%
1%
1/32
1/16
1/8
SOOT LAYER ON HEATING SURFACES

EXHIBIT 5-5

AUTOMATIC ROLL FILTER MEDIA

PERFORMANCE SUMMARY

PRODUCT DESCRIPTION:	2" Roll Media for Automatic Roll Filter Equipment
PERFORMANCE:	
Maximum Initial Resistance (static)	0.18 in. W.G.
Minimum Average Synthetic Dust Weight Arrestance (Steady State)	83%
Minimum Dust Holding Capacity (Dynamic)	90 grams per square foot
TEST CONDITIONS:	
Filter Face Velocity	500 FPM
Upper Operating Resistance at 100% R.A.F.	0.50 in. W.G.
Lower Operating Resistance at 100% R.A.F.	0.40 in. W.G.

This performance data is for bid test information on two rolls of filter media. The manufacturer shall have the two rolls of media tested by an independent, commercially operated test laboratory approved by the purchaser. The independent lab shall test media procured on the open market. The rolls are to be tested in accordance with ASHRAE 52-76, Section 11-2, Dynamic Procedure for Self Renewable Devices.

EXHIBIT 6-1

DISPOSABLE PANEL FILTER

PERFORMANCE SUMMARY

PRODUCT DESCRIPTION:	Disposable fiberglass panel filters
	Nominal Average Arrestance: 80-85%
	*Nominal Filter Size: 24"W x 24"H x 2"D
PERFORMANCE:	
Minimum Average Arrestance	81%
Minimum Dust Holding Capacity Per Filter	120 grams
TEST CONDITIONS:	
Filter Face Velocity	500 FPM
Test Air Flow Rate	2,000 CFM
Final Resistance	.5" W.G.

This performance data is to be used on bid specifications requiring three filters to be fully tested to ASHRAE 52-76 by an independent test laboratory. The laboratory to randomly acquire the filters on the open market.

*To certify disposable panels with dimensions other than above, the vendor should submit a 24" x 24" x 2" test sample of the media proposed. Successful performance of the test sample will be considered an indication of satisfactory performance of media when purchased with different physical dimensions than the test sample.

EXHIBIT 6-2

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION			
WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C	.	

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air Handler/Supply Fans			
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)				M	Q	S	A
SAFETY	01-10	Observe all appropriate safety precautions. WARNING: If unit is controlled by computer, it may start without warning. Disconnect must be locked out at all times except while performing operational checks in Sections 2-10, 3-10, 4-60, 5-10, 6-10, 6-20, and 7.				X	X	X	X
	01-20	Due to the need to enter a confined space, two employees will be required to perform PM checks in Sections 2-20 and 5-30 through 5-90. The maintenance supervisor must be notified when employee enters and upon completion.					X	X	X
	01-30	Wear appropriate personal protective equipment, i.e. gloves, safety glasses, and head protection.				X	X	X	X
FILTER UNIT	02-10	Operational check--Check operation of automatic filter unit. NOTE: The air handler will not be placed in service without a filter in place.				X	X	X	X
	02-20	Check filter media for proper tracking, sagging between rolls, separation, and mounting of filter rolls.					X	X	X
	02-30	Check operation of end of filter alarm.						X	X
	02-40	Check for excessive hunting of manometer gauge, if equipped; reset gauge cocks as required.					X	X	X
	02-50	Clean and lubricate filter advance mechanism.						X	X
BELTS & SHEAVES	03-10	Operational check--Start unit, listen for excessive belt slippage at start, belt slap, or any unusual noises.				X	X	X	X
	03-20	Remove belt guard. NOTE: Make sure unit is locked out.						X	X
	03-30	Check V-belts for proper tension, cracks, and excessive wear. (Reference HBK MS-43.)						X	X

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EXHIBIT 6-3

U.S. POSTAL SERVICE MAINTENANCE CHECK LIST	IDENTIFICATION: WORK CODE		EQUIP. ACRONYM					NUMBER	TYPE
	0	3	H	V	A	C			

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air Handler/Supply Fans			
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	FREQUENCY			M	Q	S	A
BELTS & SHEAVES (Continued)	03-40	Check sheaves for damage or excessive wear.						X	X
	03-50	Check for proper alignment of motor and fan sheaves.						X	X
	03-60	Check taper lock bushing on motor and fan shaft for tightness, cracks, missing or broken keys, bolts, and proper fit to shafts.						X	X
	03-70	Replace belt(s).							X
MOTOR	04-10	Check motor mounting for cracks and mounting bolts for tightness.						X	X
	04-20	Check motor shaft for excessive end play.						X	X
	04-30	Clean motor of dirt and debris to ensure cooling.						X	X
	04-40	Remove bearing grease relief plug. Lubricate motor bearings. Reinstall grease relief plug after motor has run for 15 minutes.							X
	04-50	Reinstall belt guard.						X	X
	04-60	Operational check--Start motor, check for excessive noise, vibration, and heat.				X	X	X	X
FAN AND COILS	05-10	Operational check--Start unit, check for excessive noise, and vibration.				X	X	X	X
	05-20	Lubricate fan bearings. Wipe fittings clean.						X	X
	05-30	Remove fan access cover. NOTE: Make sure unit is locked out.							X
	05-40	Check fan for loose blades, tightness of fan setscrews and shaft keys.							X
	05-50	Clean bearings of excessive grease and dirt.							X
	05-60	Check bearing locking collar and setscrews for tightness.						X	X

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EXHIBIT 6-3 (Continued)

U.S. POSTAL SERVICE MAINTENANCE CHECK LIST	IDENTIFICATION: WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
	03	HVAC		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air Handler/Supply Fans			
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	M	Q	S	A
FAN AND COILS (Continued)	05-70	Check condition of fan chamber insulation/liner.				X
	05-80	Clean hot and chilled water coils. Clean fan and fan cage.				X
	05-90	Reinstall fan access cover.				X
	05-100	Check structural members, vibration eliminators, and flexible connectors.				X
ELECTRICAL	06-10	Check all electrical connections and terminals for tightness and signs of heating on components, i.e. relays, terminal strips, freeze stats, and motor starter. NOTE: Unit must be locked out.				X
	06-20	Check for burned or badly pitted contacts on relays and motor starter.				X
	06-30	Check starter and relays contact housings for heat damage. NOTE: Unit must be replaced if damage is found.				X
	06-40	Clean out motor control center compartment.				X
CONTROLS, VALVES, AND DAMPERS		(PNEUMATIC) OPERATION/CALIBRATION				
	07-10	Check hot water valve for air, water, leaks, and calibration. Valve should fully open and fully close at proper psi values.				X
	07-20	Check chilled-water valve for water, air, leaks, and calibration. Valve should fully close and fully open at proper psi values.			X	X
	07-30	Check minimum outside air temperature (OAT) damper motor and lines for leaks and operation. This damper will be open at all times air handler is running.			X	X
	07-40	Check main outside air damper motors and lines for leaks and calibration. Dampers should start to open and fully open at recommended psi values.			X	X

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EXHIBIT 6-3 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION: WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Air Handler/Supply Fans			
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	M	Q	S	A
CONTROLS, VALVES, AND DAMPERS (Continued)	07-50	Check return-air damper motor and lines for leaks and calibration. Dampers should fully open and fully close at recommended psi values.			X	X
	07-60	Check exhaust air damper motor and lines for leaks and calibration. Dampers should be fully open and fully closed at recommended psi values.			X	X
	07-70	Replace filters in sensors.				X
	07-80	Replace filter in electric pressure (EP) relays.				X
	07-90	Lubricate all damper linkage with dry film lubricant.			X	X
	07-100	Check calibration of freeze stat.				X
	07-110	Replace filter in controller.				X
	07-120	Calibrate controller.			X	X
	07-130	Check calibration/operation of pressure electric (PE) relays, if equipped.		X	X	
	07-140	Check/drain filter/regulator station bowl as needed.		X	X	X
	07-150	Check all controls and control lines for air leaks.			X	X
	07-160	Check operation/calibration of discharge temperature gauges and general monitoring system (GMS) sensor.			X	X
GENERAL	08-10	Clean exterior of entire air handler, ducts, and inlet screws of all dirt, oil, and debris. Touch up paint as required.			X	X
	08-20	Clean work area of tools, rags, and equipment used for the PM.			X	X

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EXHIBIT 6-3 (Continued)

U.S. POSTAL SERVICE
MAINTENANCE CHECK LIST

IDENTIFICATION										
WORK CODE		EQUIP. ACRONYM				NUMBER				TYPE
0	3	H	V	A	C					

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Pumps			
SUB-EQUIPMENT/AREA	DATE LAST REVISED	REVISION NO.	APPROVED BY (INITIALS)

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	M	Q	S	A
SAFETY	01-10	Observe all appropriate safety precautions.	X	X	X	X
MECHANICAL SEALS	02-10	Check mechanical seal for leaks with pump both stopped and running.	X	X	X	X
	02-20	Check mechanical seal lubricating/cooling lines for water flow during operation.	X	X	X	X
	02-30	Clean mechanical seal lubricating/cooling filter seperator lines as required.				X
PUMP BEARINGS	03-10	Check bearings for excessive noise, heat and vibration with pump in operation.	X	X	X	X
	03-20	Check for oil leaks at oil seals and around bearing housing.	X	X	X	X
	03-30	Check oil level in bearing oil cups. Refill with lube as required.	X	X	X	X
	03-40	Drain and refill bearing oil cups.				X
	03-50	Check pump mounting and top pump flange for tightness.				X
COUPLING	04-10	Check coupling inserts for cracks, excessive hardness and deterioration.			X	X
	04-20	Check coupling set screws for tightness.			X	X
	04-30	Check coupling keys and keyways for wear or damage.			X	X
	04-40	Check coupling for alignment with dial indicator. Make sure motor mounting bolts are tight prior to checking.				X
PUMP PNEUMATIC VALVE	05-10	Check valve manual operation.			X	X
	05-20	Check valve automatic operation. Place pump in hand position. Pump motor should start, valve should open slowly and smoothly. Turn pump motor off. Valve should close slowly and smoothly.	X	X	X	X

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EXHIBIT 6-4

SAMPLE

U.S. POSTAL SERVICE MAINTENANCE CHECK LIST	IDENTIFICATION: WORK CODE	EQUIP. ACRONYM	NUMBER	TYPE
	0 3	H V A C		

SYSTEM/LOCATION	EQUIPMENT TYPE	MODEL/SERIES	ORIGINAL ISSUANCE DATE
Pumps			
SUB-EQUIPMENT/AREA	**DATE LAST REVISED**	**REVISION NO.**	**APPROVED BY (INITIALS)**

PART OR COMPONENT	ITEM NO.	INSTRUCTIONS (COMPLY WITH ALL CURRENT SAFETY PRECAUTIONS)	M	Q	S	A
MOTOR	06-10	Check motor for excessive noise, heat and vibration.	X	X	X	X
	06-20	Remove bearing grease relief plug. Lubricate motor bearings. Reinstall relief plug after motor has run for 15 minutes.			X	X
ELECTRICAL	07-10	Check motor starter and relay contacts. Replace contacts if excessively pitted or burnt.			X	X
	07-20	Check all terminals for tightness and signs of overheating.			X	X
	07-30	Clean all components, cabinets interior and exterior.			X	X
	07-40	Check for missing covers and loose conduit.			X	X
GAUGES	08-10	Check operation and calibration of suction and discharge side gauges. Set gauge cock to dampen gauge oscillation to prevent wear.	X	X	X	X
GENERAL	09-10	Reinstall covers/guards removed during PM.				
	09-20	Clean pump, motor and platform. Touch up paint as required.				

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EXHIBIT 6-4 (Continued)

Maintenance Handbook MS-24

Heating, Cooling, and Ventilating

UNITED STATES POSTAL SERVICE™

Heating, Cooling, and Ventilating

Maintenance Handbook
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