through the outlet reasonably low, and to avoid fluctuation of the water line and undue entrainment of moisture. It should extend vertically to the maximum height available above the boiler, but with a minimum of at least 2 ft. A steam velocity in boiler outlets not exceeding 25 to 30 fps at maximum load is recommended, unless data are available to show that a higher velocity is satisfactory. See further data on pipe connections to boilers in Chapters 8 and 12 of the 1964 GUIDE AND DATA BOOK and in the *ASME Boiler Construction Code for Low Pressure Heating Boilers.*

Where a *return header* is used on a cast iron sectional boiler to distribute the condensate to both rear tappings, it is advisable to provide full size plugged tees instead of elbows where the branch connections enter the return tappings. This aids in cleaning of sludge from the bottom of the boiler sections through the large plugged openings. An equivalent cleanout plug should be provided in the case of a single return connection.

Blowoff or drain connections should be made near the boiler, and arranged so that the entire system may be drained of water by opening the drain cock. In the case of two or more boilers, separate blowoff connections must be provided for each boiler, on the boiler side of the stop valve on the main return connection.

Water service connections must be provided for both steam and water boilers, for refilling, and for the addition of make-up water to boilers. This connection is usually of galvanized steel pipe, and is made to the return main near the boiler or boilers.

Fitting connections for pressure gage piping, water gage connections, and safety valves should be made in accordance with the *ASME Boiler Construction Code for Low Pressure Heating Boilers.*

Smoke Breeching and Chimney Connections. The breeching or smoke pipe from the boiler outlet to the chimney should be airtight and as short and direct as possible, preferably long-radius and 45-deg instead of 90-deg bends. The breeching entering a brick chimney should not project beyond the flue lining, and, where practicable, it should be grouted from the inside of the chimney. A thimble or sleeve is usually provided where the breeching enters a brick chimney.

Where a battery of boilers is connected into a breeching, each boiler should be provided with a tight damper installed in conformity with local ordinances. Good connections made to a good chimney will usually result in a rapid response by the boilers to demands for heat.

ERECTION, OPERATION, AND MAINTENANCE

The directions of the boiler manufacturer should always be read before the assembly or installation of any boiler is started, even though the contractor may be familiar with the boiler. All joints that require boiler putty or cement, which cannot be reached after assembly is complete, must be finished as the assembly progresses.

Five precautions that should be taken in all installations to prevent damage to the boiler are:

1. There should be provided proper and convenient drainage connections for use if the boiler is not in operation during freezing weather.
2. Strains on the boiler, due to movement of piping during expansion, should be prevented by suitable anchoring of piping, and by proper provision for pipe expansion and contraction.
3. Direct impingement of too intense local heat upon any part of the boiler surface, as with oil burners, should be avoided by protecting the surface with firebrick or other refractory material.
4. Condensation in steam systems must flow back to the boiler as rapidly and uniformly as possible. Return connections should prevent the water from backing out of the boiler.
5. Automatic boiler feeders and low water cut-off devices, which shut off the source of heat if the water in the boiler falls below a safe level, are recommended for mechanically-fired boilers.

Boiler Troubles

Generally, a complaint regarding boiler operation will be due to one of the following:

1. *The boiler fails to deliver enough heat.* The cause of this condition may be: (*a*) poor draft, (*b*) poor fuel, (*c*) inferior attention or firing, (*d*) boiler too small, (*e*) improper piping, (*f*) improper arrangement of sections, (*g*) heating surfaces covered with soot, (*h*) insufficient radiation installed, or (*i*) with mechanical firing, fuel-burning equipment too small.
2. *The water line is unsteady.* The cause of this condition may be: (*a*) grease and dirt in boiler, (*b*) water column connected to a very active section and, therefore, not showing actual water level in boiler, or (*c*) boiler operating at excessive output.
3. *Water disappears from the gage glass.* This may be caused by: (*a*) priming due to grease and dirt in boiler, (*b*) too great pressure difference between supply and return piping preventing return of condensate, (*c*) valve closed in return line, (*d*) connection of bottom of water column to a very active section or thin waterway, or (*e*) improper connections between boilers in battery permitting boiler with excess pressure to push returning condensate into boiler with lower pressure.
4. *Water is carried over into steam main.* This may be caused by: (*a*) grease and dirt in boiler, (*b*) insufficient steam dome or too small steam liberating area, (*c*) outlet connections of too small area, (*d*) excessive rate of output, (*e*) water level carried higher than specified.
5. *Boiler is slow in response to operation of dampers.* This may be due to: (*a*) poor draft resulting from air leaks into chimney or breeching, (*b*) inferior fuel, (*c*) inferior attention, (*d*) accumulation of clinker on grate, or (*e*) boiler too small for the load.
6. *Boiler requires too frequent cleaning of flues.* This may be due to: (*a*) poor draft, (*b*) smoky combustion, (*c*) too low a rate of combustion, or (*d*) too much excess air in firebox causing chilling of gases.
7. *Boiler smokes through fire door.* This may be due to: (*a*) defective draft in chimney or incorrect setting of dampers, (*b*) air leaks into boiler or breeching, (*c*) gas outlet from firebox plugged with fuel, (*d*) dirty or clogged flues, or (*e*) improper reduction in breeching size.
8. *Low carbon dioxide.* This may be due in oil burning boilers to: (*a*) improper adjustment of the burner, (*b*) leakage through the boiler setting, (*c*) improper fire caused by a fouled nozzle, or (*d*) to an insufficient quantity of oil being burned.

Cleaning New Boilers

All boilers are provided with flue cleanout openings through which the heating surface can be reached by means of brushes or scrapers. Flues of solid fuel boilers should be cleaned often to keep the surfaces free of soot or ash. Gas boiler flues and burners should be cleaned at least once a year. Oil-burning boiler flues should be examined periodically to determine when cleaning is necessary to remove soot deposits.

The grease used to lubricate the cutting tools during erection of new piping systems serves as a carrier for sand and dirt, with the result that a scum of the fine particles and grease accumulates on the surface of the water in all new boilers, and heavier particles may settle to the bottom of the boiler and form sludge. These impurities tend to cause foaming, preventing the generation of steam and causing an unsteady water line.

It is important (to prevent damage to accessories used in the heating system) that such cleaners be completely removed from the boiler either by wash out with high-pressure water from a hose or by draining and refilling the boiler several times after the compound has been used. Some manufacturers of boilers have found that the best cleaning results are obtained by using the surface blowoff method described in the next two paragraphs and depending on it for removal of the sludge and dirt rather than on a boil-out compound to clean the boiler.

Many boilers are equipped with a surface blowoff tapping, 1½ in. or over, at the height of the normal water line to permit removal of the scum of fine particles and grease that collect at the surface of the water when new systems are first put in operation. For sludge removal this tapping is connected by a full-size short nipple to a gate valve from which piping leads to a convenient disposal point.

The procedure is as follows: Raise water level to center of blowoff tapping. With fuel burning at rated input, and boiler steaming at 5 to 10 psig, open the valve suddenly to secure removal of the scum. Repeat the procedure until the water appears to be clear. Then shut off the burner or draw the fire and drain the boiler. Refill with fresh water to the water line when the boiler is cool and raise the water temperature to 212 F to remove the absorbed oxygen and other gases from the water.

When addition of water to a system in service becomes necessary it is advisable to operate the boiler or at least to raise the water temperature to the boiling point in order to permit escape of oxygen and other dissolved gases that would be corrosive if the boiler were not put in operation immediately.

If rapid waterline fluctuations or priming occur in an old boiler system, the trouble may be due to: (1) an accumulation of mud or minerals carried in with the water supply, (2) products of corrosion, or (3) over-treatment with compound. Draining, followed by washing out with high-pressure water from a hose will usually correct the trouble. In severe cases, repeated washing or boil-out may be necessary.

Treatment of Boiler Water

Corrosion on the water side of a boiler can be minimized by proper treatment of the boiler water. Generally, treatment which will remove the dissolved oxygen and carbon dioxide and maintain a minimum *pH* of 11 (slightly alkaline water) will effectively minimize corrosion. Sodium sulfite is useful as an oxygen scavenger and may be added at the rate of ¼ lb per 100 gal of water and caustic soda may be used to control the *pH*. A *pH* higher than 11 may be used although the boiler water is more likely to foam and cause wet steam with the greater concentration of alkali.

Inhibitors may be used in hot water and low-pressure steam boilers (15 lb maximum). After an extensive study, the Steel Boiler Institute adopted a conditioning compound for use with steel boilers, and many members of the Institute either supply this compound with their boilers or make it available.

It should be emphasized that when the character of the water is such that treatment is required, the treatment should be administered immediately after the boiler and system have been cleaned. It is not good practice to fill a boiler with fresh water and allow it to stand idle as the dissolved gases in fresh water available in many localities can start corrosive action in a very short time. After a system is refilled, it is advisable to elevate the temperature close to the boiling point to drive off the dissolved gases immediately.

Care of Idle Heating Boilers

Both fireside and external surfaces of boilers usually remain dry during normal operation. Since moisture is one of the primary causes of boiler deterioration, such deterioration is more likely to occur during the nonheating season than during the heating season.

With oil-fired or gas-fired boilers that are not used for summer hot water service, a preferred method of maintenance is that of keeping the boiler warm continuously by leaving the burner in operation and controlling it with a thermostat set to maintain boiler water at about 100 F. The amount of fuel burned to keep the boiler warm (and the boiler room dry) is a small cost for the protection from boiler deterioration.

At the end of the heating season, the following precautions should be taken if firing is discontinued:

1. All heating surfaces should be thoroughly cleaned of soot, ash, and residue, and the heating surfaces of steel boilers should be given a coating of lubricating oil on the fire side.
2. All machined surfaces should be coated with oil or grease.
3. Connections to the chimney should be cleaned, and in case of small boilers, the pipe should be placed in a dry place after cleaning.
4. If the boiler may be subjected to *freezing temperatures*, drain it completely and wash it out thoroughly with a hose and high-pressure water. Then dry the boiler completely by placing a small kerosine burner or similar stove in the firebox, or use a small wood fire. Exercise care to see that the boiler is completely dried out but not overheated.
5. Filled-boiler storage is usually preferred when the boiler will not be subjected to freezing temperatures. Do not drain the boiler but draw enough water off at the drain cock so that it runs clear. Then fill until the water level is in the outlet pipe and bring the temperature up to at least 200 F to drive off gases which were introduced in the feed water. If the feed water is usually treated add enough compound to treat the added water. Open all doors to keep the fireside surface dry. Leave the boiler filled to the top until the beginning of the next heating season.
6. Do not use an idle boiler for an incinerator.
7. The grates and ashpit should be cleaned.
8. Remove any rust or other deposit from exposed surfaces by scraping with a wire brush or sandpaper. After the boiler is thoroughly cleaned, apply a coat of preservative paint, where required, to external parts which are normally painted.
9. Check the firing equipment and all operating and safety controls. Any required repair work should be taken care of immediately so that the heating plant will be in good working order at the start of the next heating season.
10. Bring the water level down to the normal operating level before firing again.

PART II: WARM AIR FURNACES

A warm air furnace is a self-enclosed appliance for the purpose of heating air which is circulated through the enclosure and discharged directly into the space being heated or is more commonly conveyed through ducts to the space to be heated.

In fuel-burning furnaces, the combustion takes place within a metal-walled heat exchanger and the circulating air passes over the outside surfaces of the heat exchanger so the heat transfer takes place through the heat exchanger walls and the circulating air does not come in contact with the fuel or the products of combustion. The products of combustion are conveyed to the outside atmosphere through a flue or vent for disposal.

In an electric furnace the heating element, heated by its electric resistance, either heats the circulating air directly or through a metal sheath enclosing the resistance element.

Warm air furnaces may be categorized in several different ways: (1) the method of air circulation, (2) the intended type of fuel, (3) the intended usage (residential or commercial-industrial), and (4) the design characteristics of the heat exchanger.

Residential Warm Air Furnaces

Residential warm air furnaces are usually considered those of under 250,000 Btu output, although residential furnaces are often used in commercial installations. The reverse is usually not true since more than one residential furnace would usually be used in an extremely large home rather than a furnace intended for commercial use.

Forced Air Furnaces

Forced air furnaces are those equipped with a blower to circulate the air to be heated through the furnace enclosure,