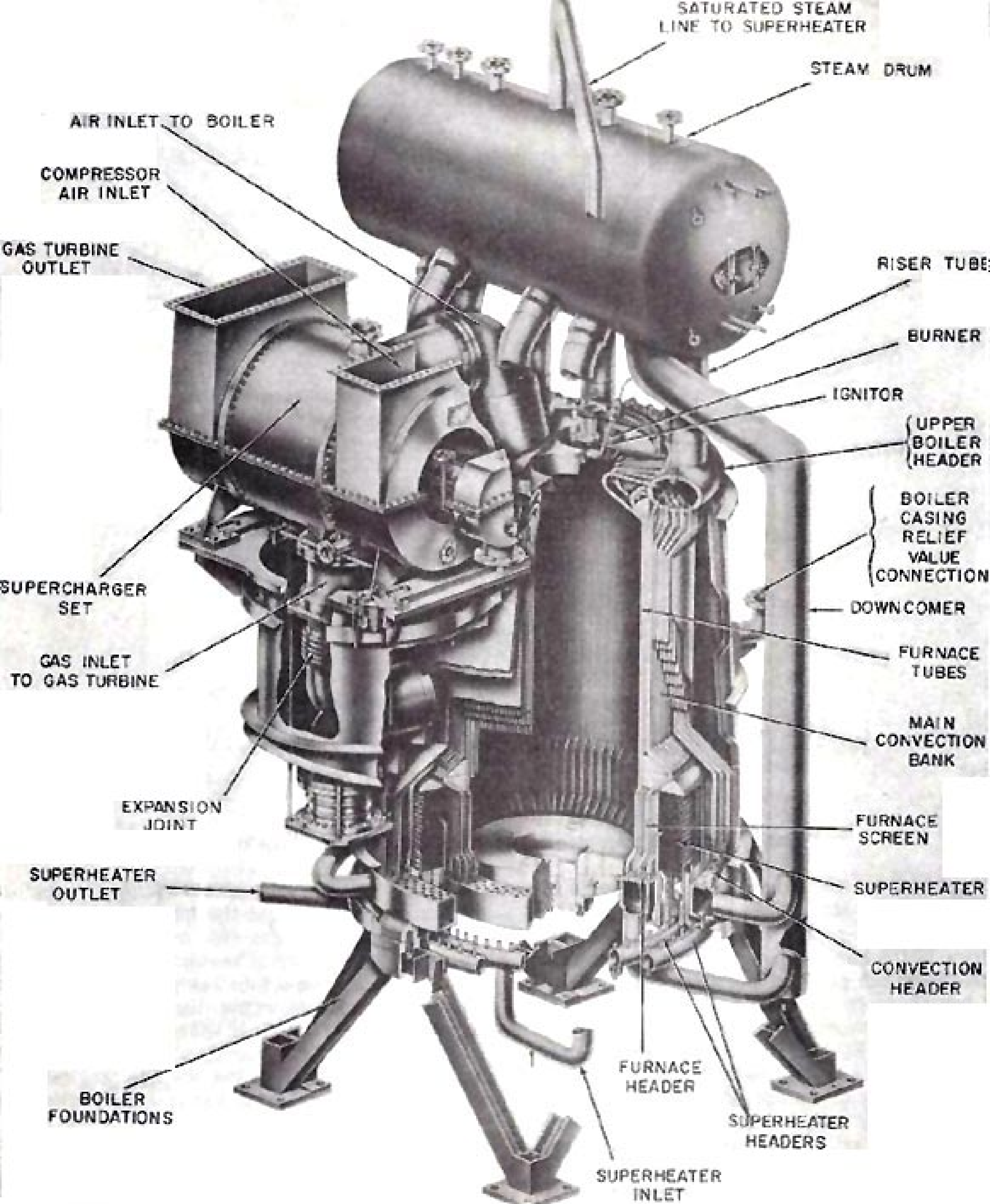

SATURATED STEAM
LINE TO SUPERHEATER
STEAM DRUM
AIR INLET TO BOILER
COMPRESSOR
AIR INLET
GAS TURBINE
OUTLET
RISER TUBE
BURNER
IGNITOR
UPPER
BOILER
HEADER
BOILER
CASING
RELIEF
VALUE
CONNECTION
DOWNCOMER
FURNACE
TUBES
MAIN
CONVECTION
BANK
FURNACE
SCREEN
SUPERHEATER
CONVECTION
HEADER
SUPERCHARGER
SET
GAS INLET
TO GAS TURBINE
EXPANSION
JOINT
SUPERHEATER
OUTLET
BOILER
FOUNDATIONS
FURNACE
HEADER
SUPERHEATER
HEADERS
SUPERHEATER
INLET

been used for some time in stationary power plants, in locomotives, and in some merchant ships. Only a few controlled circulation boilers have been installed in the propulsion plants of naval ships, and of this few the majority were subsequently removed and replaced by conventional single-furnace boilers with accelerated natural circulation. In theory, however, controlled circulation has some very marked advantages over natural circulation, and it is entirely possible that improved designs of controlled circulation boilers may be developed for future use in naval propulsion plants.

In natural circulation boilers, circulation occurs because the ascending mixture of water and steam is lighter (less dense) than the descending body of relatively cool and steam-free water. As boiler pressure increases, however, there is less difference between the density of steam and the density of water. At pressures over 1000 psi, the density of steam differs so little from the density of water that natural circulation is harder to achieve than it is at lower pressures. At high pressures, controlled circulation boilers have a distinct advantage because their circulation is controlled by pumps and is independent of differences in density. Because controlled circulation boilers can be designed without regard for differences in density, they can be arranged in practically any way that is required for a particular type of installation. Thus a greater flexibility of arrangement is possible and the boilers may be designed for compactness, savings in space and weight requirements, and maximum heat absorption.

There are two main kinds of controlled circulation boilers. One type is known as a once-through or forced flow boiler; the other type is usually called a controlled circulation or a forced recirculation boiler. In both types, external pumps are used to force the water through the boiler circuits; the essential difference between the two kinds lies in the amount of water supplied to the boiler.

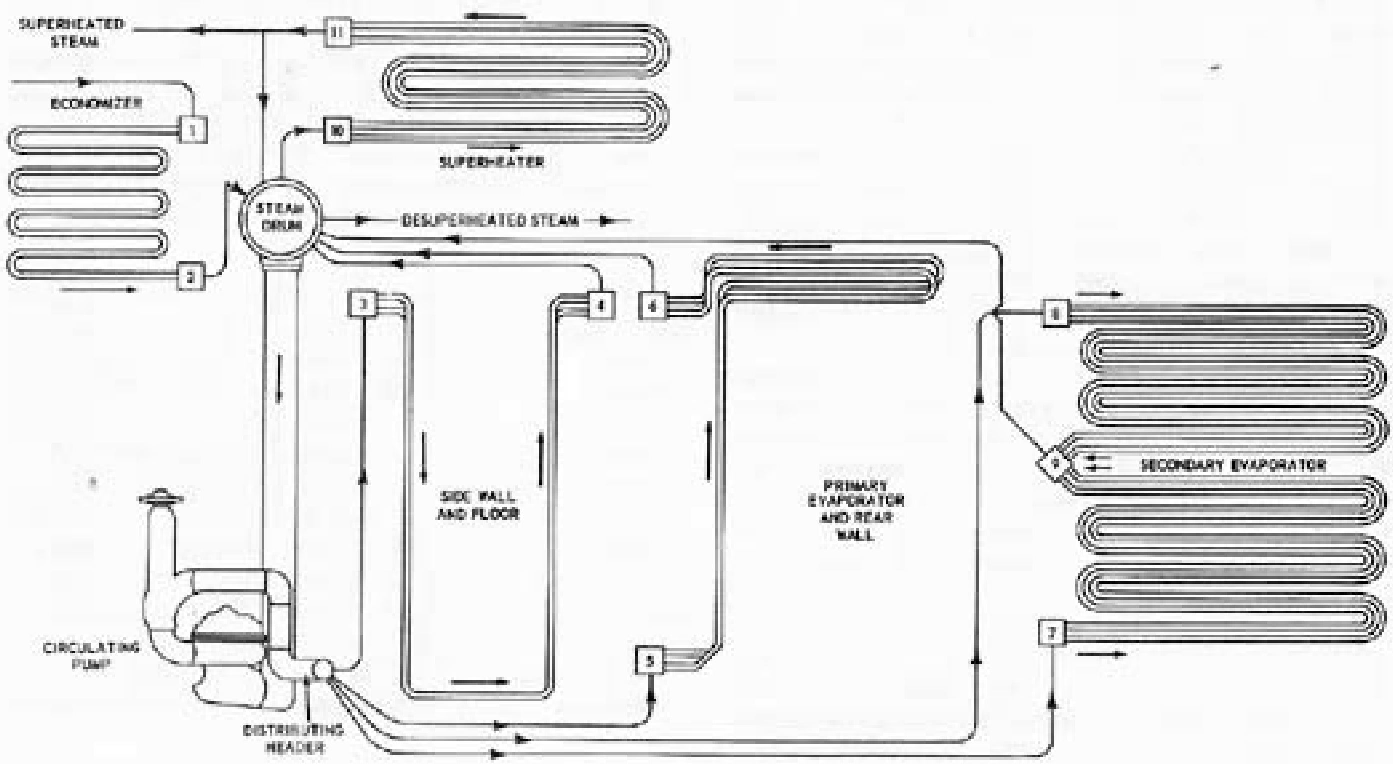
In a once-through forced circulation boiler, all (or very nearly all) of the water pumped to the boiler is converted to steam the first time through, without any recirculation. This type of boiler has no steam drum, but has instead a small separating chamber. Water is pumped into the economizer circuit and from there to the generating circuit, the amount of flow being controlled so as to allow practically all of the water to be converted into steam in the generating circuit. The very small amount of water that is not converted to steam in the generating circuit is separated from the steam in the separating chamber. The water is discharged from the separating chamber to the feed pump suction, if it is suitable for use; if it contains solid matter, it is discharged through the blowdown pipe. Meanwhile, the steam from the separating chamber flows on through the superheater circuit, where it is superheated before it enters the main steam line.

Figure 10-24 shows the boiler circuits of a controlled circulation (or forced recirculation) boiler. In this boiler, more water is pumped through the circuits than is converted into steam. The excess water is taken from the steam drum and is pumped through the boiler circuits again by means of a circulating pump. This type of boiler has a conventional steam drum which contains a feed pipe, steam separators and dryers, a desuperheater, and other fittings. The boiler has an economizer, three generating circuits, and a superheater. Circulating pumps, fitted as integral parts of the boiler, provide positive circulation to all steam generating surfaces.

Both types of controlled circulation boilers have far smaller water capacity than do natural circulation boilers, and therefore have much more rapid response to changes in load. For this reason, automatic controls are required on these boilers to ensure rapid and sensitive response to fuel and feed water requirements.

PRESSURIZED-FURNACE BOILERS.—A boiler recently developed for use in naval propulsion plants is variously known as a pressurized-furnace boiler, a pressure-fired boiler, a supercharged boiler, or a supercharged steam generating system.

A pressurized-furnace boiler is shown schematically in figure 10-25 and in cutaway view in figure 10-26. As may be seen, the boiler is quite unlike other operational boiler types in general configuration. The pressurized furnace is more or less cylindrical in shape, with the long axis of the cylinder running vertically. The boiler drum is mounted horizontally, some distance above the pressurized furnace. The drum is connected to the steam and water elements in the furnace by risers and downcomers, all of which are external to the casing. Some boilers of this type are side-fired. Others (including the one shown) are top-fired; as may be seen in figures 10-25 and 10-26, the burners are at the top



LEGEND

1. ECONOMIZER INLET HEADER
2. ECONOMIZER OUTLET HEADER
3. SIDE WALL AND FLOOR CIRCUIT INLET HEADER
4. SIDE WALL AND FLOOR CIRCUIT OUTLET HEADER
5. PRIMARY EVAPORATOR AND REAR WALL CIRCUIT INLET HEADER
6. PRIMARY EVAPORATOR AND REAR WALL CIRCUIT OUTLET HEADER
7. LOWER SECONDARY EVAPORATOR CIRCUIT INLET HEADER
8. UPPER SECONDARY EVAPORATOR CIRCUIT INLET HEADER
9. SECONDARY EVAPORATOR OUTLET HEADER
10. SUPERHEATER INLET HEADER
11. SUPERHEATER OUTLET HEADER

147.85

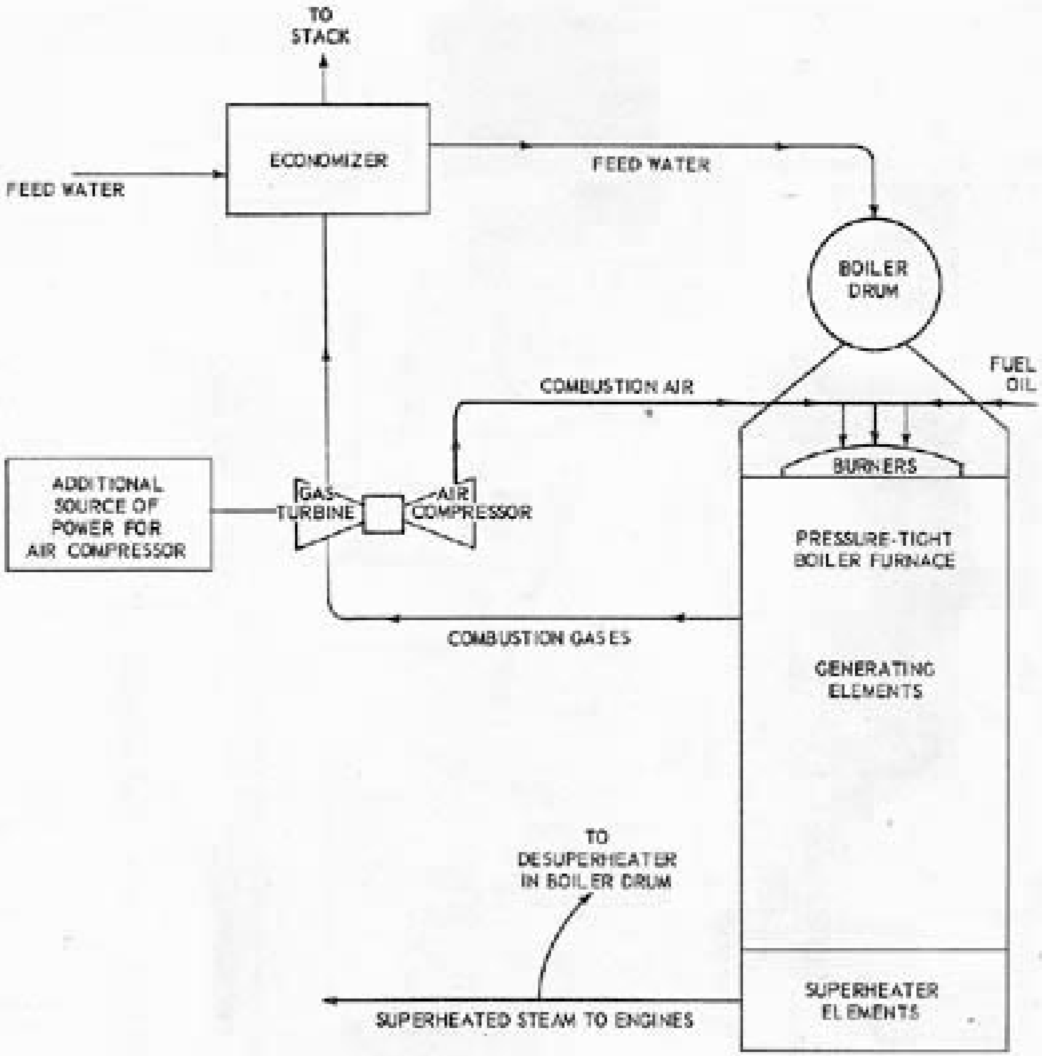
Figure 10-24.—Schematic diagram of controlled circulation boiler.

of the pressurized furnace, firing downward into the furnace.

The burners, specially designed for the pressurized-furnace boiler, are quite unlike any we have thus far considered. The burners are designed to burn distillate fuel rather than Navy Special fuel oil. There are no air register doors. There are three burners per boiler, and each burner includes a special type of straight mechanical atomizer (not return-flow) which utilizes three sprayer plates at the same time. All three burners are operated simultaneously, and all three sprayer plates remain in place in each atomizer. The sprayer plates operate in sequence to meet changing conditions of load. The design of these burners allows an enormously wide range of operation without cutting burners in or out and without even changing sprayer plates.

The generating tubes run vertically inside the pressurized furnace. The superheater is an annular pancake arrangement inserted into the bottom of the pressure vessel. The superheater is designed to be removed without disturbing the main components of the boiler.

The air compressor which supplies the combustion air under pressure is driven by a gas turbine. The air compressor and the gas turbine together are referred to as the supercharger. Part of the energy needed for driving the gas turbine is obtained from the combustion gases leaving the boiler furnace. The combustion gases expand through the gas turbine, and some of the heat is converted into work. This is the same



147.86

Figure 10-25.—Schematic view of pressurized-furnace boiler.

kind of energy transformation that occurs in a steam turbine; the difference is that hot combustion gases, rather than steam, carry the energy to the gas turbine. After the combustion gases leave the gas turbine, some of the remaining heat may be used to heat feed water as it flows through an economizer.

There are no forced draft blowers in pressurized-furnace boiler installations. The supercharger takes the place of the forced draft blowers, thus greatly increasing plant efficiency. The steam saved by the use of a supercharger instead of forced draft blowers may amount to as much as 8 or 10 percent of boiler capacity.

Altogether, a pressurized-furnace boiler is not much more than half the size and half the weight of a conventional boiler of equal steam capacity. A large part of this saving of space and weight occurs because the increased pressure[5] on the combustion gas side causes a very great increase in the rate of heat transfer to the water in the tubes. Thus a smaller generating surface is required to generate the same amount of steam. Another cause of space and weight saving is that the general design of the pressurized-furnace boiler eliminates the need for much of the refractory material that is required in other

[5] Forced draft blowers for conventional boiler installations furnish air pressures ranging from 0 to 10 psig. In a pressurized-furnace boiler, the air compressor supplies combustion air at pressures ranging from 30 to 90 psig.

boilers. A pressurized-furnace boiler may require only about 2000 pounds of refractory, as against the 21,000 pounds or more usually required in a conventional boiler of equal capacity.

Increased efficiency, a substantial saving in space and weight requirements, a substantial reduction in ship's force maintenance requirements, shorter boiler start-up time, and better maneuverability and control are the major advantages of the pressurized-furnace boiler. Although some operational and maintenance problems do exist with this boiler, it appears likely that most of them can eventually be solved by increased training of personnel, increased precision in the erection of the boilers, and perhaps continued refinements of design and construction.