farthest away from the burner. The smaller units are provided with a 3-pass, S-shaped gas path and an exit at the front end, left-hand drawing, p 101.

Both medium-size and smaller boilers have watercooled baffles, and all the tubes in their first pass are placed more widely apart than those of their second or third pass. Then, too, designers reduce the volumetric size of these corridors from the first to the second, or on to the third, to maintain uniform velocity throughout the gas travel in face *of the cooling of combustion products.*

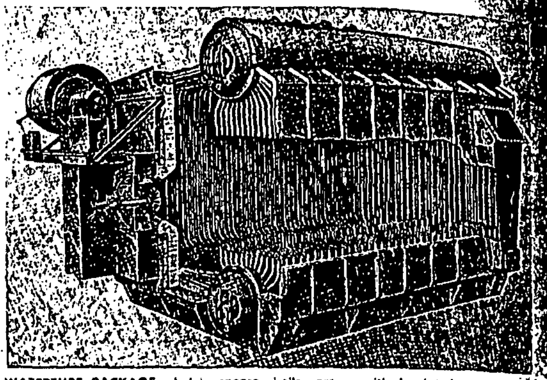
In either design, single- or 2-drum, the relatively high ratio of furnace-wall cooling to furnace volume offers rapid and efficient heat absorption—hence, lower gas temperatures entering the convection bank.

Water Circulation. Both types have their feedwater entry in the steam drum, *and it is here that their oval-shaped* water circulation begins and terminates. The single-drum boiler has two such circuits, one on either side of the drum. Fresh water courses down the outer sets of tubes, through the sidewall headers, and back up to the drum bottom by way of the furnace-wall tubes.

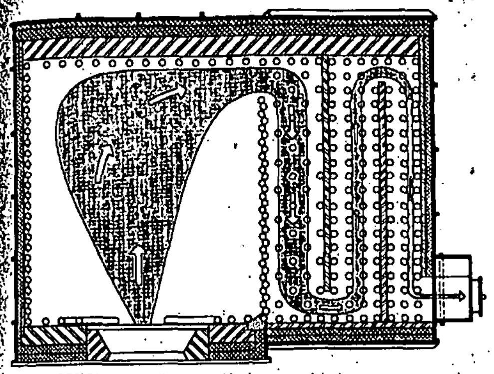
The 2-drum boiler also has two separate water circuits. However, one is inside the other. All the incoming water passes down the outer half of the direct drum-connecting tubes. In the mud drum much of the feedwater rises up through the inner-half portion of these tubes, while the remainder travels up through the waterwalls, and so on back to the upper drum.

Front ends of the sidewall headers of the single-drum design prove the coolest sections of this type boiler. Their location in the tail-end of the gas travel, and, too, in the dead-pocket area surrounding the burner's mouth, produces this comparative coolness. These two spots are, therefore, where the greatest sludge accumulation is expected. Surprisingly, though, absence of any sludge build-up here does not indicate a clean boiler, as you might suppose, but serves rather as a sign that scale formation *has probably developed elsewhere* in the unit. Since these sidewall headers act also as feeders for the highly sensitive waterwalls, it is most vital to avoid excessive sludge pile-up here. Otherwise, fireside tubes then become dangerously fouled. Hence, you need a close control over blowdown.

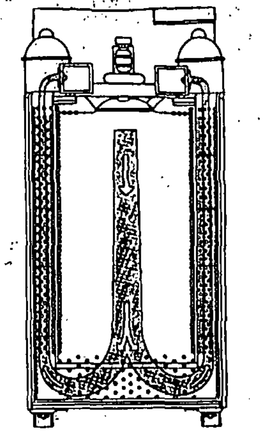
In the 2-drum design, the relatively large mud drum ordinarily affords



WATERTUBE PACKAGE wholely encases boiler proper with insulated steel jacket; suitable for either indoor or outdoor installation; it requires no special foundation



TWO-DRUM DESIGN, depending on steaming capacity, has one, two or three gas passes like the above. Largest units have only one pass, with no convection baffling



SINGLE-DRUM unit's one gas pass splits at back and returns to front dual exits

High Ratio of Wall-Cooling to Furnace Volume Gives Rapid Heat Absorption and Heightens Water-Treatment Needs

ample protection against any appreciable sludge recirculation. Sludge accumulation is more apt to be heaviest in the drum end beneath the gas exit. The rapid water circulation in these boilers, however, makes it good operation to exercise careful blowdown.

Scale Formation. The waterwall tubes, exposed to the radiant heat of the furnace, constitute the principal heat-absorbing elements of these boilers. As such, they suffer most from the insulating effect scale produces. Because of the greater heat-transfer rate, it takes far less deposit to overheat these tubes than any of the others. Moreover, the higher the pressure, the thinner the scale need be, and the quicker such tubes blister.

The silicate type of scale is denser than the sulfate, which is, in turn, somewhat more so than the carbonate. Their degree of impedance to heat transfer follows this same order. So, at the higher pressures, only a paper-thin silicate scale is enough to bring frequent tube failures in the waterwalls. But in the cooler section of the boiler and at *moderate-to-low operating pressures*, as much as 1/16 in. of carbonate deposit may be sustained for considerably longer periods. Any form of scale, though, is most undesirable. Once silicate deposits, it proves extremely difficult to remove either mechanically or chemically. The overall heat loss may be only negligible because of later recovery in the convection stages. But the damage and maintenance that scale causes is an entirely different story. They can be quite costly.

Corrosion. If makeup water is not properly deaerated, you can expect serious corrosion. The relatively cool feedwater, introduced into the steam drum, comes in contact with the hot boiler water at the end of its circulation cycle. Release of dissolved oxygen from the fresh water follows. This corrosive gas may then pit the drum proper along its water-level belt or proceed to corrode the down-comer tubes. Some of this gas escapes with the steam and later joins with carbon dioxide of the condensate to attack the return lines.

Carryover. The large upper drum of a watertube packaged boiler affords adequate steam space and, in addition, room for mechanical steam-purifying facilities as well. Thus, these units are not prone to carryover problems unless pushed to fairly high ratings or made to carry unfavorably high boiler-water solids content.

Embrittlement. The all-welded drum seams of these units greatly minimize *any possibility of intercrystalline* cracking occurring from local caustic concentration in strained joints. But, as with all boilers, you must (1) avoid developing exceedingly strong caustic alkalinities (2) always watch out for any embrittling tendencies, especially at the rolled-in tube ends. Where any are suspected, run extensive and conclu*sive tests and take corrective steps.*

External Treatment. Ordinarily with *a goodly all-year average of returns* and a clear water supply of low-to-moderate hardness, no presoftening need be applied to the makeup water for boilers operating up to 150 psi. From 150 to 250 psi, raw-water hardness would have to be fairly low and volume of recovered condensate consistently high to justify use of internal treatment alone. *Above 250 psi, the desired internal boil*er conditions can rarely be attained or maintained without the aid of external treatment.

A raw water having both its hardness and alkalinity quite high would be subject to lime-soda softening. A combination of moderately high hardness and fairly low alkalinity renders the sodium *zeolite method of softening ideal.* In some instances, it may prove sound to (1) couple sodium zeolite with hydrogen zeolite or (2) supplement lime softening alone with sodium zeolite. Still other cases may call for either acid or caustic follow-up to presoftening. In any event, the makeup water's physical and chemical characteristics and the specific feedwater composition for a particular operating pressure dictate what makes the more economical and efficient system. Don't forget, though, with external conditioning, you always need some measure of boiler internal treatment as well.

Corrosion Correction. Feedwater can't be just preheated, for good boiler operation. You must also deaerate it. The thing to do is to expel as much dissolved gas by mechanical means as practicable. Raw water always introduces both oxygen and carbon dioxide gases. And, in addition, as the water's natural bicarbonate alkalinity breaks down, more carbon dioxide builds up in the boiler cycle. Proper deaeration rids the feedwater of practically all of these two gases.

Oxygen, by far the more corrosive, can be completely eliminated with sodium sulfite, which absorbs oxygen to produce the highly soluble and harmless sodium sulfate salt. By constantly carrying a slight excess of sulfite in the boiler water, you insure the absence of oxygen. Volatile organic amines fed into boiler water neutralize carbon dioxide *gas in the steam.* But you can't recover these chemicals, and so justifying their relatively high cost is always a difficulty.

If you use a steel economizer, inject a little caustic soda. While caustic soda is somewhat hazardous to handle and difficult to regulate, it is non-gas-producing and serves to restrain carbon dioxide action, which would otherwise *develop at this elevated temperature.* Controlled recirculation of a small portion of boiler water also gives a similar effect.

Calcium Correction. As previously recommended for firetube-type packaged boilers (Power, June, p 76), the phosphate-organic treatment has thus far proven the more effective of boiler internal corrective methods. It precipitates the boiler water's concentrating calcium hardness in the form of tricalcium phosphate. This product readily falls out as a fine non-scaling powder. By consistently maintaining a slight residual of phosphate you are assured of a steady zero-hardness boiler water. Since both the phosphate and calcium can remain unreactive with each other below a pH of 10, be certain to furnish enough alkalinity to the boiler water to drive this reaction to completion. Precalculated proportioning of the various forms of phosphates will give the desired alkalinity range under any given operating conditions. An appropriate organic coagulant added at the same time combats the packing and sticking tendencies of tricalcium phosphate. If this deposit is kept fluid, blowdown removes it easily.

Magnesium Correction. Magnesium, generally the minor partner of the calcium, magnesium hardness-contributing constituents, can, however, prove quite troublesome, especially if you let it come down in the phosphate form. To avoid producing this very sticky and *uncoagulative deposit*, you'll have to carry fairly high boiler-water alkalinities. By so doing, you insure, instead, the precipitation of the gelatinous, and even helpful, magnesium hydroxide.

Silica Retention. As silica undergoes concentration in the boiler water, it acquires a growing tendency to drop out of the solution, preferably in union

(Continued on page 216)