CHAPTER XIII

COMMON DEFECTS AND REPAIRS TO SCOTCH BOILERS

AT cleaning times each boiler should be the subject of a thorough examination by a responsible engineer, and this is best accomplished to a definite routine. There are, of course, various opinions concerning the best routine to be adopted, but one suggested routine for a single-ended boiler is as follows:

(1) furnaces and back ends;
(2) bottom of boiler externally, bearers, collison chocks;
(3) bottom doors, bottom parts internally, furnaces, etc.;
(4) bottom mountings;
(5) middle mountings;
(6) top internally with tubes, chambers, furnace tops, stays, etc.;
(7) top mountings, top door, easing gear, etc.

It would be impossible in these short notes to detail all the defects which might be discovered, and it is therefore proposed to deal with only three main classes of defects, namely:

(1) wastage;
(2) overheating; and
(3) the combined effect of corrosion and mechanical action.

WASTAGE

Beginning with the upper parts of the boiler, wastage of the shell round defective mounting joints, as in Fig. 112 (3), of parts exposed to the atmosphere and also of nuts securing the mountings to the shell are common occurrences. Proceeding to the middle parts of the boiler, wastage is often caused by leakage past defective rivets in circumferential, cross and longitudinal seams, Fig. 112 (14), leakage past stay nuts, Fig. 112 (29), and in the case of the front tube plate, leakage past defective tube ends, Fig. 112 (10).

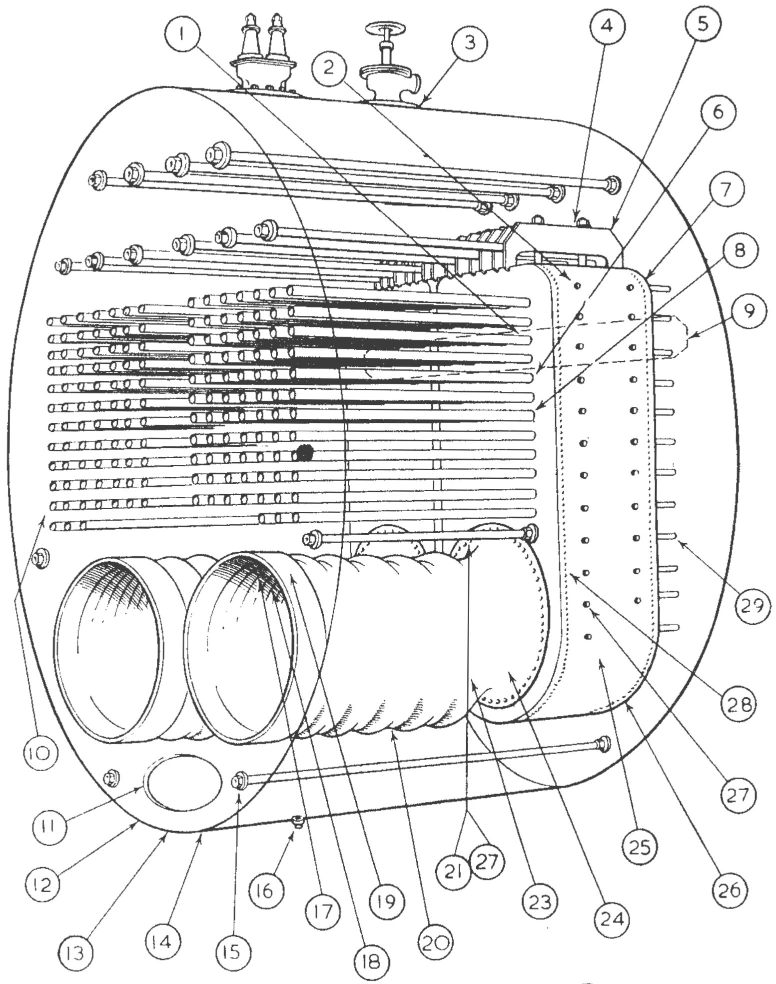
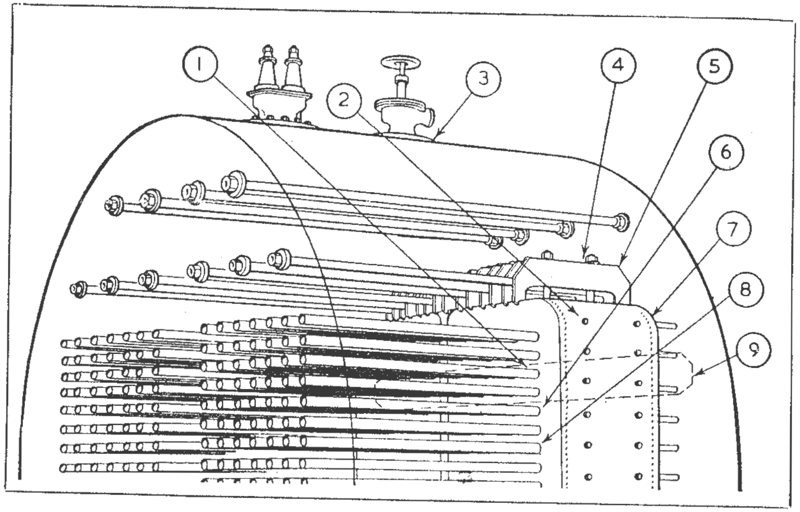


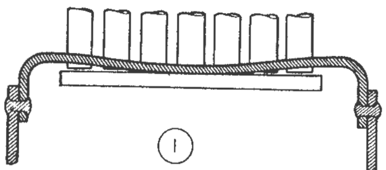
FIG. 112.—DEFECTS AND REPAIRS TO SCOTCH BOILERS

This diagram illustrates the parts of a Scotch boiler where defects are most likely to be found, and which should be carefully examined when the boiler is being cleaned.

The appearance of these defects is shown in the enlarged views on the following pages.

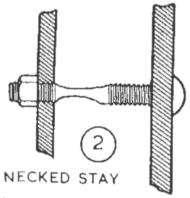
The causes of the faults and the methods of repair are dealt with in detail in pp. 203–11.





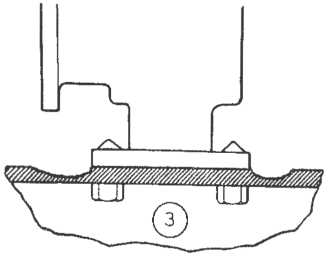
DISTORTED CHAMBER TUBE PLATES

1. The pushing of the tube plate inwards is caused by the tubes having been allowed to become encrusted with scale, with subsequent overheating.



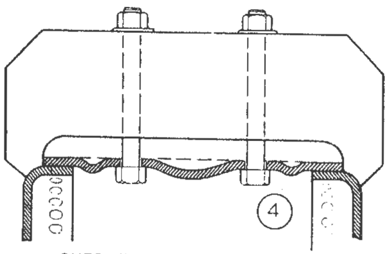
NECKED STAY

2. "Necking", or wastage of a stay tube or stay where it enters the plate, is a very common wastage defect.



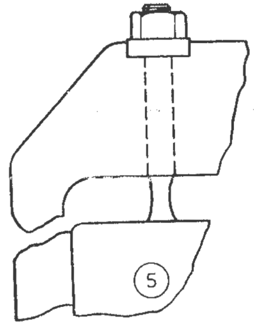
WASTAGE OF SHELL DUE TO DEFECTIVE JOINT

3. In the upper parts of the boiler, wastage should be looked for in parts exposed to the atmosphere, at nuts securing mountings, and, as shown above, around mounting joints.



OVERHEATED CHAMBER TOP

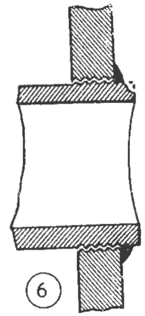
4. Another defect due to overheating is distortion of the chamber crown. Accumulation of mud scale or other insulating medium may cause this.



WASTAGE OF GIRDER STAYS CHAMBER KNUCKLES AND GIRDERS

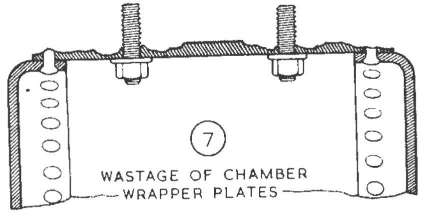
5. The remedy for the type of serious internal wastage shown is to renew the stays and girders where necessary, build up chamber landings and re-bed the girders.

6. Wastage may be caused by stay tubes leaking at the threads. Welding around the ends will not provide sufficient anchorage for the tube.

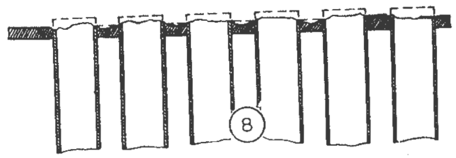


INCORRECTLY WELDED STAY TUBE

7. Wrapper plates are often found to be badly wasted, especially around the stays and over the seams. In bad cases a new section of wrapper must be riveted and welded in.



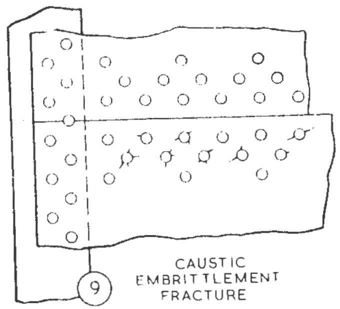
WASTAGE OF CHAMBER WRAPPER PLATES



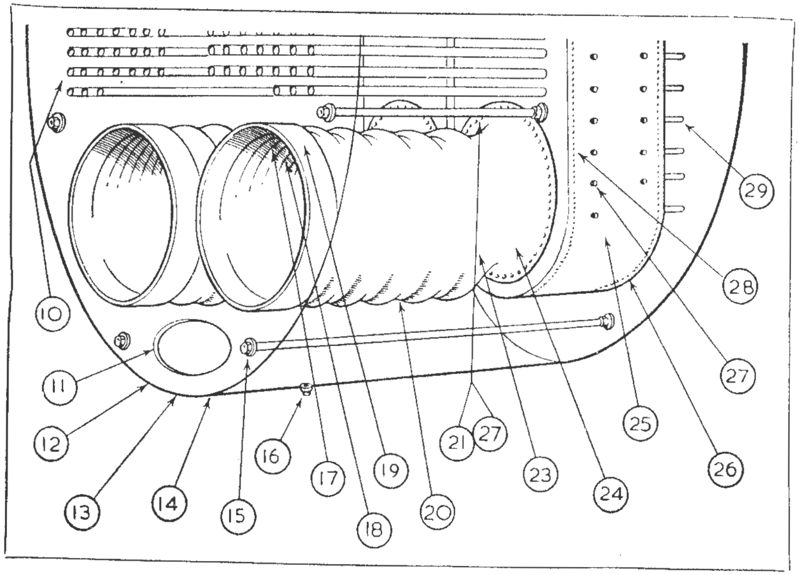
WASTAGE CAUSED BY TUBE BLOWERS

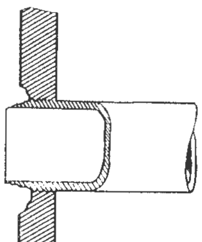
8. The use of wet steam for tube blowing may cause erosion and wastage at the tube plates and tube ends.

9. Leakage past defective rivets, especially in longitudinal seams, should always be viewed with suspicion. If rivet heads in vicinity are missing or fly off under hammer test, a magnetic crack detector may reveal caustic embrittlement.



CAUSTIC EMBRITTLEMENT FRACTURE

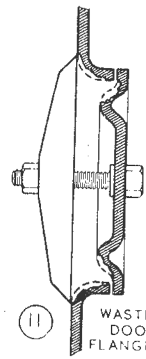




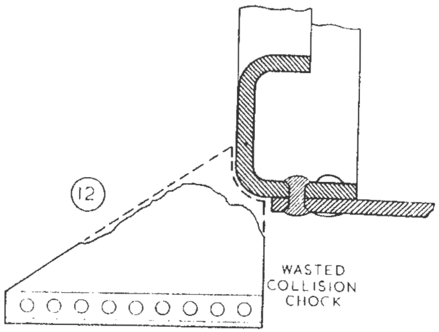
10 WASTAGE DUE TO LEAKAGE AT TUBE ENDS

10. The front tube plate should be examined for wastage caused by leakage past defective tube ends.

11. Wastage caused through leakage of manhole-door joints is very common. Doors are sometimes built up by electric welding without paying attention to the end plate, resulting in weakening of manhole flanging and eventual distortion.

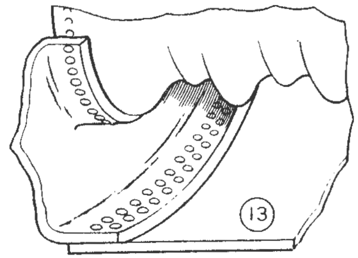


11 WASTED DOOR FLANGING



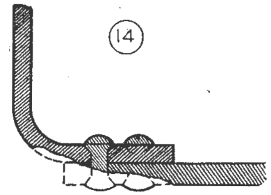
12 WASTED COLLISION CHOCK

12. Constant quenching of ashes below the furnace mouths causes end-plate wastage, and is also responsible for wastage of the collision chock immediately below.



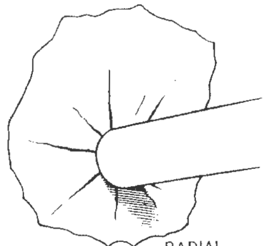
13 GROOVING OF FRONT END PLATE

13. Grooving of a fine and sometimes deep nature may be found in front end plates which are flanged inwards to take the furnaces, especially if the radius of the flanging is small.



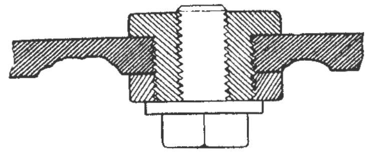
14 WASTAGE DUE TO LEAKY RIVETS

14. Wastage may be caused by leakage through defective rivets in circumferential seams, especially if the boiler has been subjected to rapid steam raising without any attempt at circulation.



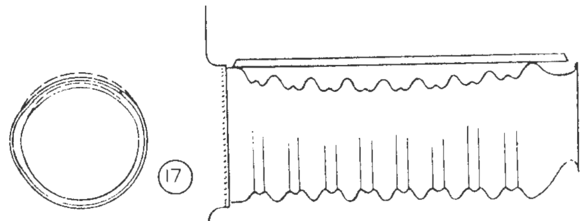
15 RADIAL GROOVING AROUND STAYS

15. Grooving is the result of mechanical action caused by varying expansion of the heating surfaces, and it may develop around lower longitudinal stays.



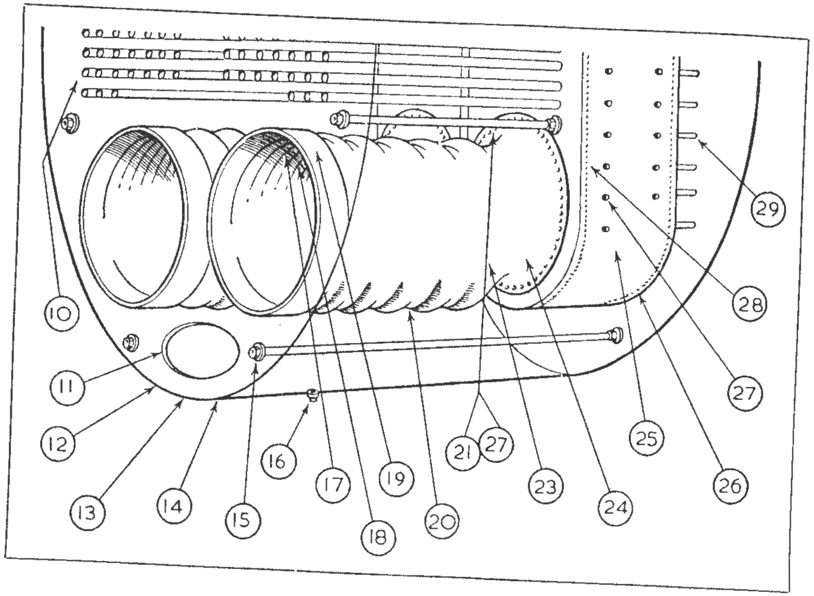
16 WASTING OF SHELL DUE TO LEAKING DRAIN PLUG

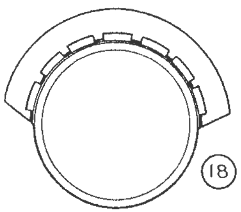
16. Drain plugs, if fitted, should always be examined. Badly fitting plugs are dangerous and often cause serious external wastage.



17 CHECKING FURNACE FOR DISTORTION

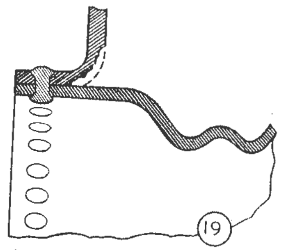
17. Overheating may cause deformation of furnaces. The amount of distortion may be checked by taking a lath inside the boiler and laying it along the corrugations at, say, four points. A method of temporary repair for distortion is shown in (18).





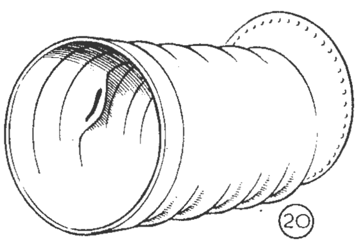
WELDED ON
FURNACE STIFFENER

18. If a distorted furnace has already been jacked up, welded stiffeners may be fitted as a temporary repair.



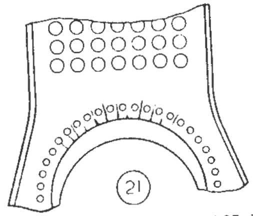
WASTAGE OF FRONT END
PLATE FLANGING TO FURNACES

19. Front end plates which are flanged outwards to take the furnaces may be found to be badly wasted over the bend of the flangings, especially at the top.



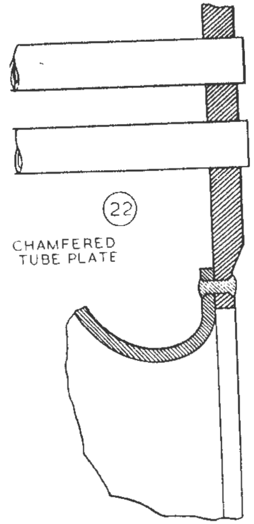
LOCAL BULGE IN FURNACE

20. Local bulges in furnaces are remedied either by cutting out the bulged portion and welding in a new piece, or by heating and pushing back into original shape. In the latter case the furnace is cut through in way of the bulge to facilitate the flow of the heated material, and the cut afterwards welded up.



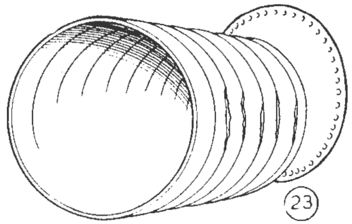
LANDING CRACKS IN FURNACE TO
CHAMBER ATTACHMENT SEAM

21. If landing cracks in combustion-chamber seams (see 27) extend beyond the line of rivets, or cause leakage, they should be cut out and filled in by electric welding.



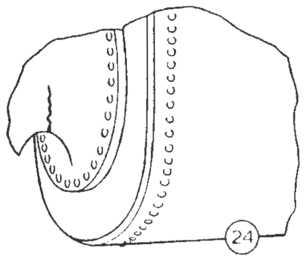
CHAMFERED
TUBE PLATE

22. To avoid overheating due to an excessive local thickness of material, it is usual to taper off the combustion-chamber tube plate in way of the furnace-attachment seam.



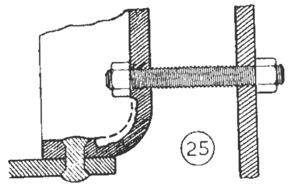
WASTAGE ALONG LINE OF FIREBARS

23. Wastage along the line of and above the firebar level is common. It usually starts with wastage of the peaks of the corrugations and may develop into a belt running along the sides of the furnace. This may cause hinging and the possibility of fracture.



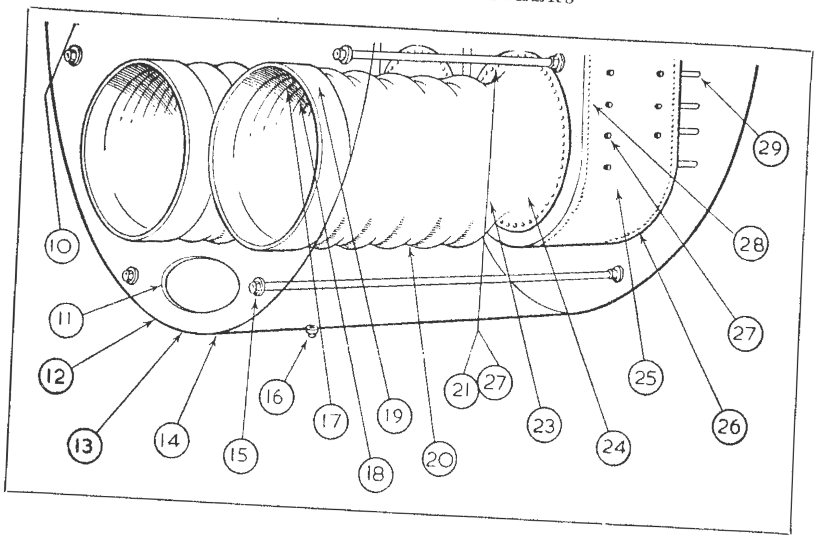
GROOVING IN FURNACE NECK

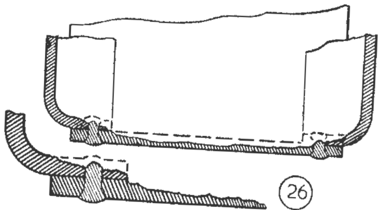
24. Grooving is a break in the structure of the material due to continual hinging action, and may occur at the bottom of the furnace neck. Repair consists of cutting out and welding, or, if more serious, cutting right through the plate in way of the grooving.



WASTAGE OF CHAMBER BACK
BENEATH BOTTOM ROW STAYS

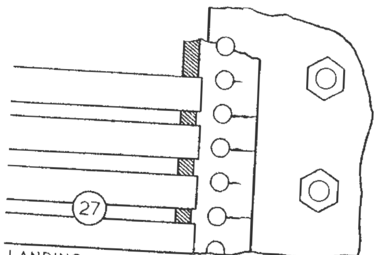
25. Wastage of combustion-chamber plating round leaky screwed stays is remedied by removing the stay, building up the plate by electric welding, retapping and fitting a new stay.





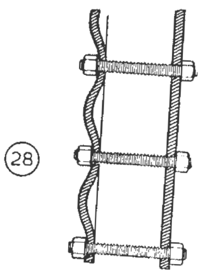
WASTAGE OF COMBUSTION CHAMBER BOTTOM WRAPPER DUE TO SEAM LEAKAGES

26. Combustion chambers are very prone to wastage defects through leakages. If a chamber bottom appears thin, a drill test will ascertain whether smooth wastage of bottom wrappers has taken place.



LANDING CRACKS IN COMBUSTION CHAMBER

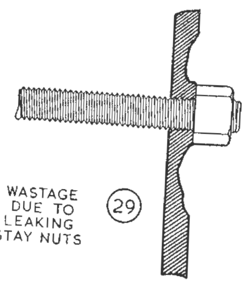
27. Other defects in combustion chambers may be caused by overheating. Landing cracks, running from the plate edge to the rivet holes, may develop on the fire side, but are not serious unless very numerous and causing leakage.



OVERHEATED CHAMBER BACK PLATE

28. The water side of the combustion chamber should be kept clean, or overheating may cause bulging of the back plate between stays.

29. Wastage is often caused by leakage past defective rivets in circumferential, cross and longitudinal seams (14) and past defective tube ends (10). Another form of wastage, due to leakage past stay nuts, is shown here.



WASTAGE DUE TO LEAKING STAY NUTS

Leakage Past Defective Rivets

Leakage past defective rivets, especially in longitudinal seams, should always be viewed with suspicion, and if subsequent hammer testing of the rivet points results in these being dislodged, the condition of the whole seam should be investigated in view of the possibility of caustic embrittlement. Rivets should be removed from various points in the seam and the holes carefully examined. If any fractures are apparent in the bores of the holes, a magnetic crack detector applied to the defective plate will reveal their extent, Fig. 112 (9). In the case of a double butt-strap joint this may necessitate the removal of the straps. However, there are other causes of rivet points breaking away from their shanks, such as defective material, overheating, initial faulty workmanship, etc., and it is well to bear this in mind.

Wastage at Mountings

It is also desirable to consider the advisability of examining the necks and joints of mountings such as check valves, scum valves, etc., *especially when these are covered with lagging.* In a recent case the necks and joints of the valves were covered with asbestos lagging and portable plates, and it was only after some persuasion that these were removed—whereupon the scum-valve chest was found to be badly salted up around the neck, and during the chipping operations necessary to remove the salt the chest broke away from the neck holding it to the boiler shell.

Circumferential Seam Leakage

The lower parts of the boiler also call for attention. Wastage is very often found where there has been circumferential seam leakage, Fig. 112 (14), especially if the boiler has been subjected to such ill-treatment as rapid steam raising without any attempt at circulation. Here again a recent case showed the shell to be so wasted under the lagging in way of a circumferential seam leakage that a hammer test pierced the shell plate. The repair for this defect consisted of an internal riveted patch welded on to and forming an extension of the end-plate flanging.

Leakage at Manhole-door Joints

Wastage caused through the leakage of manhole-door joints is very common, and it is worth noting that the doors are sometimes built up by electric welding without paying attention to the end plate, with the result that although the door is made a passable fit, the lower part of the manhole flanging is gradually weakened, and eventually fails to react equally all round to the pull of the door dogs, Fig. 112 (11), thereby producing distortion.

Wastage of End Plate and Collision Chocks

The constant quenching of ashes below the furnace mouths causes wastage of the end plate, which, on account of its smooth nature, may easily be missed. It is also responsible for the wastage of the collision chock immediately below, Fig. 112 (12). A point concerning collision chocks is that some makers favour a chock in the form of a small doubler on the boiler shell which bears against one of the boiler stools. If, therefore, an examination fails to reveal the presence of a normal-type chock, one of this variety may be found hidden from view beneath the lagging.

Leaking Drain Plugs

When examining the lower part of the boiler internally it is essential to ascertain whether or not a drain plug is fitted, in order that its condition may be noted when the external examination of the shell is being made. Badly fitting drain plugs, apart from being dangerous, often cause serious external wastage, Fig. 112 (16).

Wastage of Combustion Chambers

In addition to the external parts of the shell, the fire side of the furnaces and combustion chambers must be considered. The fire side of the furnaces can be more or less ruled out as far as wastage is concerned, unless this takes place as a result of leaky seams. Owing to the number of their seams and the severe racking strains to which they are subjected, combustion chambers are, however, very prone to wastage defects through leakages, shown in Fig. 112 (26). The smooth wastage of combustion-chamber bottom wrappers is a particularly elusive type of defect. The seams are a good guide in this matter, but if the plate is judged to be seriously reduced, drill tests will confirm any doubt. In cases where a chamber bottom appears thin and its seams have been previously welded over, a drill test is essential.

Wastage of Stay-tube Threads

Tubes, both stay and plain, of dirty boilers are liable to overheat and cause excessive expansion, with consequent working of the tubes in their tube plates, the result being a leakage and wasting of the stay-tube threads.

If stay-tubes leak at the threads and cause local wastage, expanding may, if the threads are good, constitute a cure, but on no account should they be welded around the ends, as the shear resistance of this small fillet weld may be the only anchorage of the tube, Fig. 112 (6).

The above remark concerning the welding of stay-tube ends is also applicable to the nutless type of combustion-chamber screwed stay.

Wastage of Combustion-chamber Plating

Wastage of combustion-chamber plating around leaky screwed stays, especially beneath those in the back bottom row, is fairly common, Fig. 112 (25), and can nearly always be remedied by removing the stay, building up the plate by electric welding, re-tapping and fitting a new stay.

Before leaving combustion chambers, there is another form of wastage which should be mentioned, the combined effect of erosion and wastage caused by a high-pressure jet of wet steam impinging on some part of the chamber. This defect is often caused by the use of wet steam for tube blowing, in which case the tube plates and tube ends suffer, Fig. 112 (8), or through serious leakage at a defective seam, stay-nut or tube.

Internal Wastage

Neglected boilers, and particularly 'tween-deck auxiliary boilers, are liable to suffer from wastage on practically all their internal surfaces, and common defects are serious wastage of the combustion-chamber girders, stays and knuckles of the tube and back plates, Fig. 112 (5). It is quite usual to find the girder toes wasted to such an extent that they are clear of the chamber. The remedy for this is to renew the stays and girders where necessary, build up chamber landings where required and re-bed the girders.

Wastage of Wrapper Plates

Wrapper plates are frequently found to be badly wasted, especially around the stays and over the seams, Fig. 112 (7), and in bad cases the only thing to be done is to cut out the defective portion of wrapper and to rivet and weld in a new section. Sometimes it is only a matter of wastage around the stays, and in this case the usual repair is to remove the latter and build up a compensating pad on the fire side by electric welding, re-tap and fit new stays. An alternative method of repair is to remove the stays and, working with extra long electrodes through the stay holes in the boiler back plate, to build up the wasted places and refit the stay.

When dealing with wastage over wrapper seams, it should always be borne in mind that the chamber is in compression, and provided that the rivets are not seriously reduced and the seam is tight, wastage of the wrapper outside of the line of rivets is not a very serious matter, Fig. 112 (7).

Wastage of the combustion-chamber tube plates around the stay tubes and the back plates around stays is a frequent occurrence, and here also electric welding can be employed to make good the wastage after the tube or stay has been removed.

Wastage of Stay Tubes and Stays

In the lower parts of the boiler, wastage of a stay tube or stay at the point where it enters the plate—usually known as " necking " Fig. 112 (2)—is one of the most common wastage defects. It is accelerated by the straining imposed on the stays by the expansion and contraction of the combustion-chamber due to temperature changes.

A point to remember with wasted stays is that their strength varies as the square of the diameter and that it is quite a simple matter to compare the smallest wasted diameter with the diameter at the bottom of the thread.

Stay tubes sometimes blister and pit, the pits being small and deep. Such pits can be quite enough to condemn the stay tubes, although their strength may not appear to be affected. On the other hand, the stay tubes may be so badly wasted that only the removal of a tube can give any guide as to their general condition. This course was recently taken in the case of a 'tween-deck donkey boiler, the stay tubes removed being only one-third of the weight of the new tubes replacing them.

Wastage of Furnace

Wastage of furnaces along the line of and above the firebar level is a very common occurrence which is often serious. It

usually starts with a wastage of the peaks of the corrugations, and if not checked or made good by electric welding, this rapidly develops into a belt running along the sides of the furnace, Fig. 112 (23). The result of any such wasting at the sides is a tendency for hinging along the line of weakness and a possibility of subsequent fractures. Drill testing, gauging, careful examination and, if possible, an insight into its previous history must serve to decide whether or not a furnace is still in a safe condition.

Wastage at Flanges

Flanges of small radius should always be viewed with suspicion, especially when they are likely to be subjected to varying loads. Front end plates flanged outwards to take the furnaces (Fig. 112, 19) are sometimes found to be badly wasted over the bend of the flangings, especially at the top, such wastage probably being accentuated by the furnaces.

Wastage at Boiler Bottom

In neglected boilers, water which has accumulated through condensation is sometimes allowed to remain in the bottom for long periods, with the result that pitting develops. This, in conjunction with the possibility of an accumulation of corrosive deposits through poor circulation, soon turns the pitting into wasted areas. When these areas are large, drill testing and calculations based on the remaining thickness are the best means of deciding whether the shell is still able to withstand the normal working pressure without repairs.

OVERHEATING

Defects caused through overheating are liable to be developed in the furnaces, combustion chambers and tubes. It is proposed to deal with these three parts individually and to discuss the repairs.

Furnaces

Overheating and subsequent deformation of furnaces is always caused by the presence of some insulating medium between the furnace and the surrounding water. This medium can be steam, scale, mud or oil, and its effect may be further increased by local overheating due to faulty combustion. It is not proposed, however, to deal with the causes of the defects, but merely to enumerate them.

The usual way of getting some idea as to whether a furnace is passably round is to sight along the corrugations with a torch from inside the combustion chamber. If this test shows the furnace to be distorted (a matter of experience), one of the best methods of obtaining an accurate idea of how much it has altered from its original shape is to take a lath inside the boiler and lay it along the corrugations at say, four points, Fig. 112 (17).

No definite rule can be stated as to whether or not a furnace needs renewal owing to its distorted shape; age, corrosion, acuteness and area of deformation, and previous history should all be taken into account. Local bulges, Fig. 112 (20), can often be rectified by heating and pushing back into original shape. When this is done it is essential to cut the furnace through in way of the bulge in such a manner that the flow of the heated material is facilitated, the cut in the furnace being subsequently welded up.

As an alternative to this procedure, and where experienced welders are available, the bulged portion can be completely cut out and a new piece welded in place.

If a furnace is uniformly down to such an extent as to call for immediate action, provided the material is good and the surfaces not severely corroded, quite a satisfactory repair can be effected by warming up and jacking back the furnace to its original shape, care being taken to examine the furnace carefully for cracks after the jacking operation.

Occasionally one is faced with a distorted furnace, considerably corroded along the line of firebars, which has already been jacked up, and for which no spare is immediately available. As a temporary repair, jacking back to approximately original shape and the fitting of welded stiffeners, Fig. 112 (18), is sometimes resorted to.

Distorted furnaces may give rise to differences of opinion when examining boilers, but if the distortion is really serious, the only remedy is to renew the furnace.

Combustion Chambers

Overheating is responsible for numerous defects in combustion chambers, and it is proposed to start from the upper parts and work downwards.

The first part of a boiler to feel the effects of overheating through lack of water is the chamber crown. An accumulation of mud scale or other insulating medium on the top of the chamber can also cause similar defects, Fig. 112 (4).

Proceeding lower down the chamber into parts which are subjected to more intense heat, it is quite common, especially in boilers which are not kept clean, to find the back plate bulged between the stays, Fig. 112 (28). A bulged plate accumulates scale and mud, and so promotes further overheating and an extension of the bulge. Provided the bulging of the plating between stays is not very extensive and has not stretched the material in way of the stay holes, so as to cause leakage, the obvious remedy is to keep the water side of the plating as clean as possible, in order to prevent further overheating.

When the chamber plating is bulged to such an extent that it is deemed necessary to effect repairs, it is inadvisable to fit additional stays in way of bulges, as they promote the formation of further deposits and make the plates less easy to scale, added to which the extra stays with their nuts form additional local uncooled areas. The only remedy for plating in this condition is renewal.

The partial renewal of combustion-chamber backs is a very common repair, and a question which sometimes arises is whether the plating should be cut through the lines of stays or between them. A factor in favour of the first method is that the welding is in short lengths between the stay holes and not one long, continuous weld, hence the possibility of fractures from contraction stresses is more remote.

The seams of combustion chambers are liable to overheat on their fire sides, because there is a double thickness of metal between the heating surface and the surrounding water. The result is that so-called landing cracks develop, Fig. 112 (27). These cracks may run from the plate edge to the rivet holes, and when dry can be ignored, provided they are not too numerous. If, however, the cracks originating at the plate edge do not terminate at the rivet holes and tend to extend beyond the line of rivets, Fig. 112 (21), or if leakage develops in way of the cracks, they should be cut out and filled in by electric welding, the rivets in the vicinity of the cracks being removed prior to the welding operations and subsequently renewed.

The most usual place for landing cracks to develop is in the upper parts of the seam connecting the combustion chamber to the furnace, which in view of the intense heat at this seam is understandable. It is not advisable to ignore a series of such fractures in this seam, as the ligaments between the fractures might conceivably be subjected to bending stresses through variations in the length of the furnace, due to temperature changes and straining action. Nowadays, especially in the case of heavy combustion-chamber tube plates, it is usual to taper off the plate in way of the furnace-attachment seam, Fig. 112 (22), this being an obvious way of avoiding overheating due to an excessive local thickness of material.

Tubes

Tubes which are allowed to become encrusted with scale are liable to overheating defects. In the first place the tubes, especially stay tubes, are subjected to undue expansion, with the result that they tend to push the tube plate inwards, Fig. 112 (1). In a dirty boiler this can be checked by laying a straight edge across the tube plate.

Secondly, this tendency to excessive expansion causes the tubes to move, and leads to leakage at the end which has the weaker anchorage, the combustion-chamber tube-plate end.

Thirdly, the tube ends in the combustion-chamber, especially the lower rows, tend to burn and wear thin.

COMBINED EFFECT OF CORROSION AND MECHANICAL ACTION

The defects coming under this heading are practically all to be found on the water side in the lower half of the boiler. Poor circulation, rapid steam raising, continued forcing, irregular firing, lack of uniformity of stiffness in design—such faults, often accentuated by the action of indifferent feed-water, are all factors in producing the defects now claiming attention. The areas of the heating surfaces of the furnaces, combustion chambers and tubes vary according to the temperature, and it is these variations which give rise to some of the defects caused by straining or mechanical action.

Variations in the length of the furnaces are to some extent taken up by the corrugations, but the chamber-end flanging attachment is stiffer at the top of the furnace than at the bottom, due to the form of the Gourlay neck, and hinging is liable to take place at the most flexible part, *i.e.*, at the bottom. This results in what is commonly called "grooving", Fig. 112 (24), which is a break in the structure of the material due to continual hinging

action. Grooving develops with age and accelerates as the material gets weaker.

In view of the fact that there are flanged attachments at both ends of the furnace, it is only logical to expect both to be subjected to straining action. In the case of front-end plates which are flanged inwards to take the furnaces, especially if the radius of the flanging is small, grooving of a fine and sometimes deep character is not unusual, Fig. 112 (13). When the front end plate is flanged outwards to take the furnaces, grooving in the front flanging is uncommon and, if present, is usually of a broader nature, Fig. 112 (19).

Repairs for Grooving

The procedure for dealing with grooving is to pick out what appears to be the most serious part, to drill a ½- or ⅝-in. hole through it and, by examining the bore of the hole, to ascertain its depth. The repair for the grooving when it is not more than, say, 50 per cent of the plate thickness in depth, is to cut it out and weld. If, however, it is of a more serious nature, it is usually best, provided both sides of the plate are accessible for welding operations, to cut right through the plate in way of the grooving.

As has already been said, grooving is the result of mechanical action caused by varying expansion of the heating surfaces. Any variation in length of the furnace and combustion-chamber assembly with the temperature, and also that of the boiler shell due to poor circulation, leads to working of the lower parts of the boiler end-plate flangings and of the end plates where tied by stays. These defects are shown in Fig. 112 (13) and (15). The repair for grooving of the end-plate flanges is the same as for grooving in the furnace-attachment flanges—to cut out and weld.

Where radial grooving around lower longitudinal stays develops, as in Fig. 112 (15), welding does not, as a rule, constitute a permanent repair, and the local stress concentrations at the stay ends should be spread over a larger area by fitting a doubler in way of the stay, suitably riveted to the end plate.

Similar radial grooving sometimes takes place around the stay tubes and combustion-chamber side and back stays, more especially at the combustion-chamber end. The repair in this case is to remove the stay or tube, cut out the grooving, weld up and subsequently refit the stay or tube. Doubling of heating surfaces is not permissible, as this would result in overheating.