CHAPTER VII.

CONSTRUCTIVE DETAILS OF BOILERS.

LAND AND MARINE BOILERS.

369. *Q.*—Will you explain the course of procedure in the construction and setting of wagon boilers?

A.—Most boilers are made of plates three eighths of an inch thick, and the rivets are from three eighths to three fourths of an inch in diameter. In the bottom and sides of a wagon boiler the heads of the rivets, or the ends formed on the rivets before they are inserted, should be large and placed next the fire, or on the outside; whereas on the top of the boiler the heads should be on the inside. The rivets should be placed about two inches distant from centre to centre, and the centre of the row of rivets should be about one inch from the edge of the plate. The edges of the plates should be truly cut, both inside and outside, and after the parts of the boiler have been riveted together, the edges of the plates should be set up or caulked with a blunt chisel about a quarter of an inch thick in the point, and struck by a hammer of about three or four pounds weight, one man holding the caulking tool while another strikes.

370. *Q.*—Is this the usual mode of caulking?

A.—No, it is not the usual mode; but it is the best mode, and is the mode adopted by Mr. Watt. The usual mode now is for one man to caulk the seams with a hammer in one hand and a caulking chisel in the other, and in some of the difficult corners of marine flue boilers it is not easy for two men to get in. A good deal of the caulking has also sometimes to be done with the left hand.

371. *Q.*—Should the boiler be proved after caulking?

A.—The boiler should be filled with water and caulked afresh in any leaky part. When emptied again, all the joints should be painted with a solution of sal ammoniac in urine, and so soon as the seams are well rusted they should be dried with a gentle fire, and then be painted over with a thin putty formed of whiting and linseed oil, the heat being continued until the putty becomes so hard that it cannot be readily scratched with the nail, and care must be taken neither to burn the putty nor to discontinue the fire until it has become quite dry.

372. *Q.*—How should the brickwork setting of a wagon boiler be built?

A.—In building the brickwork for the setting of the boiler, the part upon which the heat acts with most intensity is to be built with clay instead of mortar, but mortar is to be used on the outside of the work. Old bars of flat iron may be laid under the boiler chime to prevent that part of the boiler from being burned out, and bars of iron should also run through the brickwork to prevent it from splitting. The top of the boiler is to be covered with brickwork laid in the best lime, and if the lime be not of the hydraulic kind, it should be mixed with Dutch terrass, to make it impenetrable to water. The top of the boiler should be well plastered with this lime, which will greatly conduce to the tightness of the seams. Openings into the flues must be left in convenient situations to enable the flues to be swept out when required, and these openings may be closed with cast iron doors jointed with clay or mortar, which may be easily removed when required. Adjacent to the chimney a slit must be left in the top of the flue with a groove in the brickwork to enable the sliding door or damper to be fixed in that situation, which by being lowered into the flue will obstruct the passage of the smoke and moderate the draught, whereby the chimney will be prevented from drawing the flame into it before the heat has acted sufficiently upon the boiler.

373. *Q.*—Are marine constructed in the same way as land boilers?

A.—There is very little difference in the two cases: the whole of the shells of marine boilers, however, should be double riveted with rivets $\frac{11}{16}$ths of an inch in diameter, and $2\frac{3}{8}$th inches from centre to centre, the weakening effect of double riveting being much less than that of single riveting. The furnaces above the line of bars should be of the best Lowmoor, Bowling, or Staffordshire scrap plates, and the portion of each furnace above the bars should consist only of three plates, one for the top and one for each side, the lower seam of the side plates being situated beneath the level of the bars, so as not to be exposed to the heat of the furnace. The tube plates of tubular boilers should be of the best Lowmoor, or Bowling iron, seven eighths to one inch thick: the shells should be of the best Staffordshire, or Thornycroft S crown iron $\frac{7}{16}$ths of an inch thick.

374. *Q.*—Of what kind of iron should the angle iron or corner iron be composed?

A.—Angle iron should not be used in the construction of boilers, as in the manufacture it becomes reedy, and is apt to split up in the direction of its length: it is much the safer practice to bend the plates at the corners of the boiler; but this must be carefully done, without introducing any more sharp bends than can be avoided, and plates which require to be bent much should be of Lowmoor iron. It will usually be found expedient to introduce a ring of angle iron around the furnace mouths, though it is discarded in the other parts of the boiler; but it should be used as sparingly as possible, and any that is used should be of the best quality.

375. *Q.*—Is it not important to have the holes in the plates opposite to one another?

A.—The whole of the plates of a boiler should have the holes for the rivets punched, and the edges cut straight, by means of self-acting machinery, in which a travelling table carries forward the plate with an equal progression every stroke of the punch or shears; and machinery of this kind is now extensively employed. The practice of forcing the parts of boilers together with violence, by means of screw-jacks, and drifts through the holes, should not be permitted; as a great strain may thus be thrown upon the rivets, even when there is no steam in the boiler. All rivets should be of the best Lowmoor iron. The work should be caulked both within and without wherever it is accessible, but in the more confined situations within the flues the caulking will in many cases have to be done with the hand or chipping hammer, instead of the heavy hammer previously prescribed.

376. *Q.*—How is the setting of marine boilers with internal furnaces effected?

A.—In the setting of marine boilers care must be taken that no copper bolts or nails project above the wooden platform upon which they rest, and also that no projecting copper bolts in the sides of the ship touch the boiler, as the galvanic action in such a case would probably soon wear the points of contact into holes. The platform may consist of three inch planking laid across the keelsons nailed with iron nails, the heads of which are well punched down, and caulked and puttied like a deck. The surface may then be painted over with thin putty, and fore and aft boards of half the thickness may then be laid down and nailed securely with iron nails, having the heads well punched down. This platform must then be covered thinly and evenly with mastic cement and the boiler be set down upon it, and the cement must be caulked beneath the boiler by means of wooden caulking tools, so as completely to fill every vacuity. Coomings of wood sloped on the top must next be set round the boiler, and the space between the coomings and the boiler must be caulked full of cement, and be smoothed off on the top to the slope of the coomings, so as to throw off any water that might be disposed to enter between the coomings and the boiler.

377. *Q.*—How is the cement used for setting marine boilers compounded?

A.—Mastic cement proper for the setting of boilers is sold in many places ready made. Hamelin's mastic is compounded as follows:—to any given weight of sand or pulverized earthenware add two thirds such given weight of powdered Bath, Portland, or other similar stone, and to every 560 lbs. weight of the mixture add 40 lbs. weight of litharge, 2 lbs. of powdered glass or flint, 1 lb. of minium, and 2 lbs. of gray oxide of lead; pass the mixture through a sieve, and keep it in a powder for use. When wanted for use, a sufficient quantity of the powder is mixed with some vegetable oil upon a board or in a trough in the manner of mortar, in the proportion of 605 lbs. of the powder to 5 gallons of linseed, walnut, or pink oil, and the mixture is stirred and trodden upon until it assumes the appearance of moistened sand, when it is ready for use. The cement should be used on the same day as the oil is added, else it will be set into a solid mass.

378. *Q.*—What is the best length of the furnaces of marine boilers?

A.—It has already been stated that furnace bars should not much exceed six feet in length, as it is difficult to manage long furnaces; but it is a frequent practice to make the furnaces long and narrow, the consequence of which is, that it is impossible to fire them effectually at the after end, especially upon long voyages and in stormy weather, and air escapes into the flues at the after end of the bars, whereby the efficacy of the boiler is diminished. Where the bars are very long it will generally be found that an increased supply of steam and a diminished consumption of coal will be the consequence of shortening them, and the bars should always lie with a considerable inclination to facilitate the distribution of the fuel over the after part of the furnace. When there are two lengths of bars in the furnace, it is expedient to make the central cross bar for bearing up the ends double, and to leave a space between the ends of the bars so that the ashes may fall through between them. The space thus left enables the bars to expand without injury on the application of heat, whereas without some such provision the bars are very liable to get burned out by bending up in the centre, or at the ends, as they must do if the elongation of the bars on the application of heat be prevented; and this must be the effect of permitting the spaces at the ends of the bars to be filled up with ashes. At each end of each bed of bars it is expedient to leave a space which the ashes cannot fill up so as to cause the bars to jam; and care must be taken that the heels of the bars do not come against any of the furnace bearers, whereby the room left at the end of the bars to permit the expansion would be rendered of no avail.

379. *Q.*—Have you any remarks to offer respecting the construction and arrangement of the furnace bridges and dampers of marine boilers?

A.—The furnace bridges of marine boilers are walls or partitions built up at the ends of the furnaces to narrow the opening for the escape of heat into the flues. They are either made of fire brick or of plate iron containing water: in the case of water bridges, the top part of the bridge should be made with a large amount of slant so as to enable the steam to escape freely, but notwithstanding this precaution the plates of water bridges are apt to crack at the bend, so that fire brick bridges appear on the whole to be preferable. In shallow furnaces the bridges often come too near the furnace top to enable a man to pass over them; and it will save expense if in such bridges the upper portion is constructed of two or three fire blocks, which may be lifted off where a person requires to enter the flues to sweep or repair them, whereby the perpetual demolition and reconstruction of the upper part of the bridge will be prevented.

380. *Q.*—What is the benefit of bridges?

A.—Bridges are found in practice to have a very sensible operation in increasing the production of steam, and in some boilers in which the brick bridges have been accidentally knocked down by the firemen, a very considerable diminution in the supply of steam has been experienced. Their chief operation seems to lie in concentrating the heat within the furnace to a higher temperature, whereby the heat is more rapidly transmitted from the furnace to the water, and less heat has consequently to be absorbed by the flues. In this way the bridges render the heating surface of a boiler more effective, or enable a smaller amount of heating surface to suffice.

381. *Q.*—Are the bridges behind the furnaces the only bridges used in steam boilers?

A.—It is not an uncommon practice to place a hanging bridge, consisting of a plate of iron descending a certain distance into the flue, at that part of the flue where it enters the chimney, whereby the stratum of hot air which occupies the highest part of the flue is kept in protracted contact with the boiler, and the cooler air occupying the lower part of the flue is that which alone escapes. The practice of introducing a hanging bridge is a beneficial one in the case of some boilers, but is not applicable universally, as boilers with a small calorimeter cannot be further contracted in the flue without a diminution in their evaporating power. In tubular boilers a hanging bridge is not applicable, but in some cases a perforated plate is placed against the ends of the tubes, which by suitable connections is made to operate as a sliding damper which partially or totally closes up the end of every tube, and at other times a damper constructed in the manner of a venetian blind is employed in the same situation. These varieties of damper, however, have only yet been used in locomotive boilers, though applicable to tubular boilers of every description.

382. *Q.*—Is it a benefit to keep the flues or tubes appertaining to each furnace distinct?

A.—In a flue boiler this cannot be done, but in a tubular boiler it is an advantage that there should be a division between the tubes pertaining to each furnace, so that the smoke of each furnace may be kept apart from the smoke of the furnace adjoining it until the smoke of both enters the chimney, as by this arrangement a furnace only will be rendered inoperative in cleaning the fires instead of a boiler, and the tubes belonging to one furnace may be swept if necessary at sea without interfering injuriously with the action of the rest. In a steam vessel it is necessary at intervals to empty out one or more furnaces every watch to get rid of the clinkers which would otherwise accumulate in them; and it is advisable that the connection between the furnaces should be such that this operation, when being performed on one furnace, shall injure the action of the rest as little as possible.

383. *Q.*—Can any constructive precautions be taken to prevent the furnaces and tube plates of the boiler from being burned by the intensity of the heat?

A.—The sides of the internal furnaces or flues in all boilers should be so constructed that the steam may readily escape from their surfaces, with which view it is expedient to make the bottom of the flue somewhat wider than the top, or slightly conical in the cross section; and the upper plates should always be overlapped by the plates beneath, so that the steam cannot be retained in the overlap, but will escape as soon as it is generated. If the sides of the furnace be made high and perfectly vertical, they will speedily be buckled and cracked by the heat, as a film of steam in such a case will remain in contact with the iron which will prevent the access of the water, and the iron of the boiler will be injured by the high temperature it must in that case acquire. To moderate the intensity of the heat acting upon the furnace sides, it is expedient to bring the outside fire bars into close contact with the sides of the furnace, so as to prevent the entrance of air through the fire in that situation, by which the intensity of the heat would be increased. The tube plate nearest the furnace in tubular boilers should also be so inclined as to facilitate the escape of the steam; and the short bent plate or flange of the tube plate, connecting the tube plate with the top of the furnace, should be made with a gradual bend, as, if the bend be sudden, the iron will be apt to crack or burn away from the concretion of salt. Where the furnace mouths are contracted by bending in the sides and top of the furnace, as is the general practice, the bends should be gradual, as salt is apt to accumulate in the pockets made by a sudden bend, and the plates will then burn into holes.

384. *Q.*—In what manner is the tubing of boilers performed?

A.—The tubes of marine boilers are generally iron tubes, three inches in diameter, and between six and seven feet long; but sometimes brass tubes of similar dimensions are employed. When brass tubes are employed, the use of ferules driven into the ends of the tubes is sometimes employed to keep them tight; but when the tubes are of malleable iron, of the thickness of Russell's boiler tubes, they may be made tight merely by firmly driving them into the tube plates, and the same may be done with thick brass tubes. The holes in the tube plate next the front of the boiler are just sensibly larger in diameter than the holes in the other tube plate, and the holes upon the outer surfaces of both tube plates are very slightly countersunk. The whole of the tubes are driven through both tube plates from the front of the boiler,—the precaution, however, being taken to drive them in gently at first with a light hand hammer, until the whole of the tubes have been inserted to an equal depth, and then they may be driven up by degrees with a heavy hammer, whereby any distortion of the holes from unequal driving will be prevented. Finally, the ends of the tubes should be riveted up so as to fill the countersink; the tubes should be left a little longer than the distance between the outer surfaces of the tube plates, so that the countersink at the ends may be filled by staving up the end of the tube rather than by riveting it over; and the staving will be best accomplished by means of a mandril with a collar upon it, which is driven into the tube so that the collar rests upon the end of the tube to be riveted; or a tool like a blunt chisel with a recess in its point may be used, as is the more usual practice.

385. *Q.*—Should not stays be introduced in substitution of some of the tubes?

A.—It appears expedient in all cases that some of the tubes should be screwed at the ends, so as to serve as stays if the riveting at the tube ends happens to be burned away, and also to act as abutments to the riveted tube—or else to introduce very strong rods of about the same diameter as a tube, in substitution of some of the tubes; and these stays should have nuts at each end both within and without the tube plates, which nuts should be screwed up, with white lead interposed, before the tubes are inserted. If the tubes are long, their expansion when the boiler is being blown off will be apt to start them at the ends, unless very securely fixed; and it is difficult to prevent brass tubes of large diameter and proportionate length from being started at the ends, even when secured by ferules; but the brass tubes commonly employed are so small as to be susceptible of sufficient compression endways by the adhesion due to the ferules to compensate for the expansion, whereby they are prevented from starting at the ends. In some of the early marine boilers fitted with brass tubes, a galvanic action at the ends of the tubes was found to take place, and the iron of the tube plates was wasted away in consequence, with rapidity; but further experience proved the injury to be attributable chiefly to imperfect fitting, whereby a leakage was caused that induced oxidation, and when the tubes were well fitted any injurious action at the ends of the tubes was found to cease.

386. *Q.*—What is the best mode of constructing the chimney and the parts in connection therewith?

A.—In sea-going steamers the funnel plates are usually about nine feet long and $\frac{3}{16}$ths thick; and where different flues or boilers have their debouch in the same chimney, it is expedient to run division plates up the chimney for a considerable distance, to keep the draughts distinct. The dampers should not be in the chimney but at the end of the boiler flue, so that they may be available for use if the funnel by accident be carried away. The waste steam pipe should be of the same height as the funnel, so as to carry the waste steam clear of it, for if the waste steam strikes the funnel it will wear the iron into holes; and the waste steam pipes should be made at the bottom with a faucet joint, to prevent the working of the funnel, when the vessel rolls, from breaking the pipe at the neck. There should be two hoops round the funnel, for the attachment of the funnel shrouds, instead of one, so that the funnel may not be carried overboard if one hoop breaks, or if the funnel breaks at the upper hoop from the corrosive action of the waste steam, as sometimes happens. The deck over the steam chest should be formed of an iron plate supported by angle iron beams, and there should be a high angle iron cooming round the hole in the deck through which the chimney ascends, to prevent any water upon the deck from leaking down upon the boiler. Around the lower part of the funnel there should be a sheet iron casing to prevent any inconvenient dispersion of heat in that situation, and another short piece of casing, of a somewhat larger diameter, and riveted to the chimney, should descend over the first casing, so as to prevent the rain or spray which may beat against the chimney from being poured down within the casing upon the top of the boiler. The pipe for conducting away the waste water from the top of the safety valve should lead overboard, and not into the bilge of the ship, as inconvenience arises from the steam occasionally passing through it, if it has its termination in the engine room.

387. *Q.*—Are not the chimneys of some vessels made so that they may be lowered when required?

A.—The chimneys of small river vessels which have to pass under bridges are generally formed with a hinge, so that they may be lowered backward when passing under a bridge; and the chimneys of some screw vessels are made so as to shut up like a spyglass when the fires are put out and the vessel is navigated under sails. In smaller vessels, however, two lengths of chimney suffice; and in that case there is a standing piece on deck, which, however, does not project above the bulwarks.

388. *Q.*—Will you explain any further details in the construction of marine boilers which occur to you as important?

A.—The man-hole and mud-hole doors, unless put on from the outside, like a cylinder cover, with a great number of bolts, should be put on from the inside with cross bars on the outside, and the bolts should be strong, and have coarse threads and square nuts, so that the threads may not be overrun, nor the nuts become round, by the unskilful manipulations of the firemen, by whom these doors are removed or replaced. It is very expedient that sufficient space should be left between the furnace and the tubes in all tubular boilers to permit a boy to go in to clear away any scale that may have formed, and to hold on the rivets in the event of repair being wanted; and it is also expedient that a vertical row of tubes should be left out opposite to each water space to allow the ascent of the steam and descent of the water, as it has been found that the removal of the tubes in that position, even in a boiler with deficient heating surface, has increased the production of steam, and diminished the consumption of fuel. The tubes should all be kept in the same vertical line, so as to permit the introduction of an instrument to scrape them; but they may be zig-zagged in the horizontal line, whereby a greater strength of metal will be obtained around the holes in the tube plates, and the tubes should not be placed too close together, else their heating efficacy will be impaired.

INCRUSTATION AND CORROSION OF BOILERS.

389. *Q.*—What is the cause of the formation of scale in marine boilers?

A.—Scale is formed in all boilers which contain earthy or saline matters, just in the way in which a scaly deposit, or rock, as it is sometimes termed, is formed in a tea kettle. In sea water the chief ingredient is common salt, which exists in solution: the water admitted to the boiler is taken away in the shape of steam, and the saline matter which is not vaporizable accumulates in process of time in the boiler, until its amount is so great that the water is saturated, or unable to hold any more in solution; the salt is then precipitated and forms a deposit which hardens by heat. The formation of scale, therefore, is similar to the process of making salt from sea water by evaporation, the boiler being, in fact, a large salt pan.

390. *Q.*—But is the scale soluble in fresh water like the salt in a salt pan?

A.—No, it is not; or if soluble at all, is only so to a very limited extent. The several ingredients in sea water begin to be precipitated from solution at different degrees of concentration; and the sulphate and carbonate of lime, which begin to be precipitated when a certain state of concentration is reached, enter largely into the composition of scale, and give it its insoluble character. Pieces of waste or other similar objects left within a marine boiler appear, when taken out, as if they had been petrified; and the scale deposited upon the flues of a marine boiler resembles layers of stone.

391. *Q.*—Is much inconvenience experienced in marine boilers from these incrustations upon the flues?

A.—Incrustation in boilers at one time caused much more perplexity than it does at present, as it was supposed that in some seas it was impossible to prevent the boilers of a steamer from becoming salted up; but it has now been satisfactorily ascertained that there is very little difference in the saltness of different seas, and that however salt the water may be, the boiler will be preserved from any injurious amount of incrustation by blowing off, as it is called, very frequently, or by permitting a considerable portion of the supersalted water to escape at short intervals into the sea. If blowing off be sufficiently practised, the scale upon the flues will never be much thicker than a sheet of writing paper, and *no excuse* should be accepted from engineers for permitting a boiler to be damaged by the accumulation of calcareous deposit.

392. *Q.*—What is the temperature at which sea water boils in a steam boiler?

A.—Sea water contains about $\frac{1}{33}$rd its weight of salt, and in the open air it boils at the temperature of 213·2°; if the proportion of salt be increased to $\frac{2}{33}$rds of the weight of the water, the boiling point will rise to 214·4°; with $\frac{3}{33}$rds of salt the boiling point will be 215·5°; $\frac{4}{33}$rds, 216·7°; $\frac{5}{33}$rds, 217·9°; $\frac{6}{33}$rds, 219°; $\frac{7}{33}$rds, 220·2°; $\frac{8}{3}$rds, 221·4°; $\frac{9}{33}$rds, 222·5°; $\frac{10}{33}$rds, 223·7°; $\frac{11}{33}$rds, 224·9°; and $\frac{12}{33}$rds, which is the point of saturation, 226°. In a steam boiler the boiling points of water containing these proportions of salt must be higher, as the elevation of temperature due to the pressure of the steam has to be added to that due to the saltness of the water; the temperature of steam at the atmospheric pressure being 212°, its temperature, at a pressure of 15 lbs. per square inch above the atmosphere, will be 250°, and adding to this 4·7° as the increased temperature due to the saltness of the water when it contains $\frac{4}{33}$rds of salt, we have 254·7° as the temperature of the water in the boiler, when it contains $\frac{4}{33}$rds of salt and the pressure of the steam is 15 lbs. on the square inch.

393. *Q.*—What degree of concentration of the salt water may be safely permitted in a boiler?

A.—It is found by experience that when the concentration of the salt water in a boiler is prevented from exceeding that point at which it contains $\frac{2}{33}$rds its weight of salt, no injurious incrustation will take place, and as sea water contains only $\frac{1}{33}$rd of its weight of salt, it is clear that it must be reduced by evaporation to one half of its bulk before it can contain $\frac{2}{33}$rds of salt; or, in other words, a boiler must blow out into the sea one half of the water it receives as feed, in order to prevent the water from rising above $\frac{2}{33}$rds of concentration, or 8 ounces of salt to the gallon.

394. *Q.*—How do you determine 8 ounces to the gallon to be equivalent to twice the density of salt water, or "two salt waters" as it is sometimes called?

A.—The density of the water of different seas varies somewhat. A gallon of fresh water weighs 10 lbs.; a gallon of salt water from the Baltic weighs 10·15 lbs.; a gallon of salt water from the Irish Channel weighs 10·28 lbs.; and a gallon of salt water from the Mediterranean 10·29 lbs. If we take an average saltness represented by a weight of 10·25 lbs., then a gallon of water concentrated to twice this saltness will weigh 10·5 lbs., or the salt in it will weigh ·5 lbs or 8 oz., which is the proportion of 8 oz. to the gallon. However, the proportion of $\frac{2}{33}$rds gives a greater proportion than 8 oz. to the gallon, for $\frac{2}{33}=\frac{1}{16}$ nearly, and $\frac{1}{16}$ of 10 lbs.=10 oz. By keeping the density of the water in a marine boiler at the proportion of 8 or 10 oz. to the gallon, no inconvenient amount of scale will be deposited on the flues or tubes. The bulk of water, it may be remarked, is not increased by putting salt in it up to the point of saturation, but only its density is increased.

395. *Q.*—Is there not a great loss of heat by blowing off so large a proportion of the heated water from the boiler?

A.—The loss is not very great. Boilers are sometimes worked at a saltness of $\frac{4}{33}$rds, and taking this saltness and supposing the latent heat of steam to be at 1000° at the temperature of 212°, and reckoning the sum of the latent and sensible heats as forming a constant quantity, the latent heat of steam at the temperature of 250° will be 962°, and the total heat of the steam will be 1212° in the case of fresh water; but as the feed water is sent into the boiler at the temperature of 100°, the accession of heat it receives from the fuel will be 1112° in the case of fresh water, or 1112° increased by 3·98° in the case of water containing $\frac{4}{33}$rds of salt—the 3·98° being the 4·7° increase of temperature due to the presence of $\frac{4}{33}$rds of salt, multiplied by 0·847 the specific heat of steam. This makes the total accession of heat received by the steam in the boiler equal to 1115·98°, or say 1116°, which multiplied by 3, as 3 parts of the water are raised into steam, gives us 3348° for the heat in the steam, while the accession of heat received in the boiler by the 1 part of residual brine will be 154·7°, multiplied by 0·85, the specific heat of the brine, or 130·495°; and 3348° divided by 130·495° is about $\frac{1}{26}$th. It appears, therefore, that by blowing off the boiler to such an extent that the saltness shall not rise above what answers to $\frac{4}{33}$rds of salt, about $\frac{1}{26}$th of the heat is blown into the sea; this is but a small proportion, and as there will be a greater waste of heat, if from the existence of scale upon the flues the heat can be only imperfectly transmitted to the water, there cannot be even an economy of fuel in niggard blowing off, while it involves the introduction of other evils. The proportion of $\frac{4}{33}$rds of saltness, however, or 16 oz. to the gallon, is larger than is advisable, especially as it is difficult to keep the saltness at a perfectly uniform point, and the working point should, therefore, be $\frac{2}{33}$rds as before prescribed.

396. *Q.*—Have no means been devised for turning to account the heat contained in the brine which is expelled from the boiler?

A.—To save a part of the heat lost by the operation of blowing off, the hot brine is sometimes passed through a number of small tubes surrounded by the feed water; but there is no very great gain from the use of such apparatus, and the tubes are apt to become choked up, whereby the safety of the boiler may be endangered by the injurious concentration of its contents. Pumps, worked by the engine for the extraction of the brine, are generally used in connection with the small tubes for the extraction of the heat from the supersalted water; and if the tubes become choked the pumps will cease to eject the water, while the engineer may consider them to be all the while in operation.

397. *Q.*—What is the usual mode of blowing off the supersalted water from the boiler?

A.—The general mode of blowing off the boiler is to allow the water to rise gradually for an hour or two above the lowest working level, and then to open the cock communicating with the sea, and keep it open until the surface of the water within the boiler has fallen several inches; but in some cases a cock of smaller size is allowed to run water continuously, and in other cases brine pumps are used as already mentioned. In every case in which the supersalted water is discharged from the boiler in a continuous stream, a hydrometer or salt gauge of some convenient construction should be applied to the boiler, so that the density of the water may at all times be visible, and immediate notice be given of any interruption of the operation. Various contrivances have been devised for this purpose, the most of which operate on the principle of a hydrometer; but perhaps a more satisfactory principle would be that of a differential steam gauge, which would indicate the difference of pressure between the steam in the boiler and the steam of a small quantity of fresh water enclosed in a suitable vessel, and immerged in the water of the boiler.

398. Q.—What is the advantage of blowing off from the surface of the water in the boiler?

A.—Blowing off from a point near the surface of the water is more beneficial than blowing off from the bottom of the boiler. Solid particles of any kind, it is well known, if introduced into boiling water, will lower the boiling point in a slight degree, and the steam will chiefly be generated on the surface of the particles, and indeed will have the appearance of coming out of them; if the particles be small the steam generated beneath and around them will balloon them to the surface of the water, where the steam will be liberated and the particles will descend; and the impalpable particles in a marine boiler, which by their subsidence upon the flues concrete into scale, are carried in the first instance to the surface of the water, so that if they be caught there and ejected from the boiler, the formation of scale will be prevented.

399. *Q.*—Are there any plans in operation for taking advantage of this property of particles rising to the surface?

A.—Advantage is taken of this property in Lamb's Scale Preventer, which is substantially a contrivance for blowing off from the surface of the water that in practice is found to be very effectual; but a float in connection with a valve at the mouth of the discharging pipe is there introduced, so as to regulate the quantity of water blown out by the height of the water level, or by the extent of opening given to the feed cock. The operation, however, of the contrivance would be much the same if the float were dispensed with; but the float acts advantageously in hindering the water from rising too high in the boiler, should too much feed be admitted, and thereby obviates the risk of the water running over into the cylinder. In some boilers sheet iron vessels, called sediment collectors, are employed, which collect into them the impalpable matter, which in Lamb's apparatus is ejected from the boiler at once. One of these vessels, of about the size and shape of a loaf of sugar, is put into each boiler with the apex of the cone turned downwards into a pipe leading overboard, for conducting the sediment away from the boiler. The base of the cone stands some distance above the water line, and in its sides conical slits are cut, so as to establish a free communication between the water within the conical vessel and the water outside it. The particles of stony matter which are ballooned to the surface by the steam in every other part of the boiler, subside within the cone, where, no steam being generated, the water is consequently tranquil; and the deposit is discharged overboard by means of a pipe communicating with the sea. By blowing off from the surface of the water, the requisite cleansing action is obtained with less waste of heat; and where the water is muddy, the foam upon the surface of the water is ejected from the boiler—thereby removing one of the chief causes of priming.

400. *Q.*—What is the cause of the rapid corrosion of marine boilers?

A.—Marine boilers are corroded externally in the region of the steam chest by the dripping of water from the deck; the bottom of the boiler is corroded by the action of the bilge water, and the ash pits by the practice of quenching the ashes with salt water. These sources of injury, however, admit of easy remedy; the top of the boiler may be preserved from external corrosion by covering it with felt upon which is laid sheet lead soldered at every joint so as to be impenetrable to water; the ash pits may be shielded by guard plates which are plates fitting into the ash pits and attached to the boiler by a few bolts, so that when worn they may be removed and new ones substituted, whereby any wear upon the boiler in that part will be prevented; and there will be very little wear upon the bottom of a boiler if it be imbedded in mastic cement laid upon a suitable platform.

401. *Q.*—Are not marine boilers subject to internal corrosion?

A.—Yes; the greatest part of the corrosion of a boiler takes place in the inside of the steam chest, and the origin of this corrosion is one of the obscurest subjects in the whole range of engineering. It cannot be from the chemical action of the salt water upon the iron, for the flues and other parts of the boiler beneath the water suffer very little from corrosion, and in steam vessels provided with Hall's condensers, which supply the boiler with fresh water, not much increased durability of the boiler has been experienced. Nevertheless, marine boilers seldom last more than for 5 or 6 years, whereas land boilers made of the same quality of iron often last 18 or 20 years, and it does not appear probable that land boilers would last a very much shorter time if salt water were used in them. The thin film of scale spread over the parts of a marine boiler situated beneath the water, effectually protect them from corrosion; and when the other parts are completely worn out the flues generally remain so perfect, that the hammer marks upon them are as conspicuous as at their first formation. The operation of the steam in corroding the interior of the boiler is most capricious —the parts which are most rapidly worn away in one boiler being untouched in another; and in some cases one side of a steam chest will be very much wasted away while the opposite side remains uninjured. Sometimes the iron exfoliates in the shape of a black oxide which comes away in flakes like the leaves of a book, while in other cases the iron appears as if eaten away by a strong acid which had a solvent action upon it. The application of felt to the outside of a boiler, has in several cases been found to accelerate sensibly its internal corrosion; boilers in which there is a large accumulation of scale appear to be more corroded than where there is no such deposit; and where the funnel passes through the steam chest the iron of the steam chest is invariably much more corroded than where the funnel does not pass through it.

402. *Q.*—Can you suggest no reason for the rapid internal corrosion of marine boilers?

A.—The facts which I have enumerated appear to indicate that the internal corrosion of marine boilers is attributable chiefly to the existence of surcharged steam within them, which is steam to which an additional quantity of heat has been communicated subsequently to its generation, so that its temperature is greater than is due to its elastic force; and on this hypothesis the observed facts relative to corrosion become to some extent explicable. Felt, applied to the outside of a boiler, may accelerate its internal corrosion by keeping the steam in a surcharged state, when by the dispersion of a part of the heat it would cease to be in that state; boilers in which there is a large accumulation of scale must have worked with the water very salt, which necessarily produces surcharged steam; for the temperature of steam cannot be less than that of the water from which it is generated, and inasmuch as the boiling point of water, under any given pressure, rises with the saltness of the water, the temperature of the steam must rise with the saltness of the water, the pressure remaining the same; or, in other words, the steam must have a higher temperature than is due to its elastic force, or be in the state of surcharged steam. The circumstance of the chimney flue passing through the steam will manifestly surcharge the steam with heat, so that all the circumstances which are found to accelerate corrosion, are it appears such as would also induce the formation of surcharged steam.

403. *Q.*—Is it the natural effect of surcharged steam to waste away iron?

A.—It is the natural effect of surcharged steam to oxidate the iron with which it is in contact, as is illustrated by the familiar process for making hydrogen gas by sending steam through a red hot tube filled with pieces of iron; and although the action of the surcharged steam in a boiler is necessarily very much weaker than where the iron is red hot, it manifestly must have *some* oxidizing effect, and the amount of corrosion produced may be very material where the action is perpetual. Boilers with a large extent of heating surface, or with descending flues circulating through the cooler water in the bottom of the boiler before ascending the chimney, will be less corroded internally than boilers in which a large quantity of the heat passes away in the smoke; and the corrosion of the boiler will be diminished if the interior of any flue passing through the steam be coated with fire brick, so as to present the transmission of the heat in that situation. The best practice, however, appears to consist in the transmission of the smoke through a suitable passage on the outside of the boiler, so as to supersede the necessity of carrying any flue through the steam at all; or a column of water may be carried round the chimney, into which as much of the feed water may be introduced as the heat of the chimney is capable of raising to the boiling point, as under this limitation the presence of feed water around the chimney in the steam chest will fail to condense the steam.

404. *Q.*—In steam vessels there are usually several boilers?

A.—Yes, in steam vessels of considerable power and size.

405. *Q.*—Are these boilers generally so constructed, that any one of them may be thrown out of use?

A.—Marine boilers are now generally supplied with stop valves, whereby one boiler may be thrown out of use without impairing the efficacy of the remainder. These stop valves are usually spindle valves of large size, and they are for the most part set in a pipe which runs across the steam chests, connecting the several boilers together. The spindles of these valves should project through stuffing boxes in the covers of the valve chests, and they should be balanced by a weighted lever, and kept in continual action by the steam. If the valves be lifted up, and be suffered to remain up, as is the usual practice, they will become fixed by corrosion in that position, and it will be impossible after some time to shut them on an emergency. These valves should always be easily accessible from the engine room; and it ought not to be necessary for the coal boxes to be empty to gain access to them.

406. *Q.*—Should each boiler have at least one safety valve for itself?

A.—Yes; it would be quite unsafe without this provision, as the stop valve might possibly jam. Sometimes valves jam from a distortion in the shape of the boiler when a considerable pressure is put upon it.

407. *Q.*—How is the admission of the water into the boiler regulated?

A.—The admission of feed water into the boiler is regulated by hand by the engineer by means of cocks, and sometimes by spindle valves raised and lowered by a screw. Cocks appear to be the preferable expedient, as they are less liable to accident or derangement than screw valves, and in modern steam vessels they are generally employed.

408. *Q.*—At what point of the boiler is the feed introduced?

A.—The feed water is usually conducted from the feed cock to a point near the bottom of the boiler by means of an internal pipe, the object of this arrangement being to prevent the rising steam from being condensed by the entering water. By being introduced near the bottom of the boiler, the water comes into contact in the first place with the bottoms of the furnaces and flues, and extracts heat from them which could not be extracted by water of a higher temperature, whereby a saving of fuel is accomplished. In some cases the feed water is introduced into a casing around the chimney, from whence it descends into the boiler. This plan appears to be an expedient one when the boiler is short of heating surface, and more than a usual quantity of heat ascends the chimney; but in well proportioned boilers a water casing round the chimney is superfluous. When a water casing is used the boiler is generally fed by a head of water, the feed water being forced up into a small tank, from whence it descends into the boiler by the force of gravity, while the surplus runs to waste, as in the feeding apparatus of land engines.

409. *Q.*—Suppose that the engineer should shut off the feed water from the boilers while the engine was working, what would be the result?

A.—The result would be to burst the feed pipes, except for a safety valve placed on the feed pipe between the engine and the boilers, which safety valve opens when any undue pressure comes upon the pipes, and allows the water to escape. There is, however, generally a cock on the suction side of the feed pump, which regulates the quantity of water drawn into the pump. But there must be cocks on the boilers also to determine into which boiler the water shall be chiefly discharged, and these cocks are sometimes all shut accidentally at the same time.

410. *Q.*—Is there no expedient in use in steam vessels for enabling the position of the water level in the boiler to determine the quantity of feed water admitted?

A.—In some steam vessels floats have been introduced to regulate the feed, but their action cannot be depended on in agitated water, if applied after the common fashion. Floats would probably answer if placed in a cylinder which communicates with the water in the boiler by means of small holes; and a disc of metal might be attached to the end of a rod extending beneath the water level, so as to resist irregular movements from the motion of the ship at sea, which would otherwise impair the action of the apparatus.

411. *Q.*—How is the proper level of the water in the boiler of a steam vessel maintained when the engine is stopped for some time, and the boiler is blowing off steam?

A.—By means of a separate pump worked sometimes by hand, but usually by a small separate engine called the Donkey engine. This pump, by the aid of suitable cocks, will pump from the sea into the boiler; from the sea upon deck either to wash decks or to extinguish fire; and from the bilge overboard, through a suitable orifice in the side of the ship.

LOCOMOTIVE BOILERS.

412. *Q.*—Will you recapitulate the general features of locomotive boilers?

A.—Locomotive boilers consist of three portions (see *fig.* 29): the barrel E, E, containing the tubes, the fire box B, and the smoke box F; of which the barrel smoke box, and external fire box are always of iron, but the internal fire box is generally made of copper, though sometimes also it is made of iron. The tubes are sometimes of iron, but generally of brass fixed in by ferules. The whole of the iron plates of a locomotive boiler which are subjected to the pressure of steam, should be Lowmoor or Bowling plates of the best quality; and the copper should be coarse grained, rather than rich or soft, and be perfectly free from irregularities of structure and lamination.

413. *Q.*—What are the usual dimensions of the barrel?

A.—The thickness of the plates composing the barrel of the boiler varies generally from $\frac{5}{16}$ths to $\frac{3}{8}$ths of an inch, and the plates should run in the direction of the circumference, so that the fibres of the iron may be in the direction of the strain. The diameter of the barrel commonly varies from 3 ft. to 3 ft. 6 inches; the diameter of the rivets should be from $\frac{11}{16}$ths to $\frac{3}{4}$ths of an inch, and the pitch of the rivets or distance between their centres should be from $\frac{1}{8}$7th to 2 inches.

414. *Q.*—How are the fire boxes of a locomotive constructed?

A.—The space between the external and internal fire boxes forms a water space, which must be stayed every $4\frac{1}{2}$ or 5 inches by means of copper or iron stay bolts, screwed through the outer fire box into the metal of the inner fire box, and securely riveted within it: iron stay bolts are as durable as copper, and their superior tenacity gives them an advantage. Sometimes tubes are employed as stays. The internal and external fire boxes are joined together at the bottom by a ⊔-shaped iron, and round the fire door they are connected by means of a copper ring $1\frac{1}{4}$ in. thick, and 2 in. broad,—the inner fire box being dished sufficiently outward at that point, and the outer fire box sufficiently inward, to enable a circle of rivets $\frac{3}{4}$ of an inch in diameter passing through the copper ring and the two thicknesses of iron, to make a water-tight joint. The thickness of the plates composing the external fire box is in general $\frac{3}{8}$ths of an inch if the fire box is circular, and from $\frac{3}{8}$ths to $\frac{1}{2}$ inch if the fire box is square; and the thickness of the internal fire box is in most cases $\frac{7}{16}$ths if copper, and from $\frac{3}{8}$ths to $\frac{7}{16}$ths of an inch if of iron. Circular internal fire boxes, if made of iron, should be welded rather than riveted, as the rivet heads are liable to be burnt away by the action of the fire; and when the fire boxes are square each side should consist of a single plate, turned over at the edges with a radius of 3 inches, for the introduction of the rivets.

415. *Q.*—Is there any provision for stiffening the crown of the furnace in a locomotive?

A.—The roof of the internal fire box, whether flat as in Stephenson's engines, or dome shaped as in Bury's, requires to be stiffened with cross stay bars, but the bars require to be stronger and more numerous when applied to a flat surface. The ends of these stay bars rest above the vertical sides of the fire box; and to the stay bars thus extending across the crown, the crown is attached at intervals by means of stay bolts. There are projecting bosses upon the stay bars encircling the bolts at every point where a bolt goes through, but in the other parts they are kept clear of the fire box crown so as to permit the access of water to the metal; and, with the view of facilitating the ascent of the steam, the bottom of each stay bar should be sharpened away in those parts where it does not touch the boiler.

416. *Q.*—Is any inconvenience experienced from the intense heat in a locomotive furnace?

A.—The fire bars in locomotives have always been a source of trouble, as from the intensity of the heat in the furnace they become so hot as to throw off a scale, and to bend under the weight of the fuel. The best alleviation of these evils lies in making the bars deep and thin: 4 or 5 inches deep by five eighths of an inch thick on the upper side, and three eighths of an inch on the under side, are found in practice to be good dimensions. In some locomotives a frame carrying a number of fire bars is made so that it may be dropped suddenly by loosening a catch; but it is found that any such mechanism can rarely be long kept in working order, as the molten clinker by running down between the frame and the boiler will generally glue the frame into its place. It is therefore found preferable to fix the frame, and to lift up the bars by the dart used by the stoker, when any cause requires the fire to be withdrawn. The furnace bars of locomotives are always made of malleable iron, and indeed for every species of boiler malleable iron bars are to be preferred to bars of cast iron, as they are more durable, and may if thin be set closer together, whereby the small coal or coke is saved that would otherwise fall into the ash pit. The ash box of locomotives is made of plate iron a quarter thick: it should not be less than 10 in. deep, and its bottom should be about 9 in. above the level of the rails. The chimney of a locomotive is made of plate iron one eighth of an inch thick: it is usually of the same diameter as the cylinder, but is better smaller, and must not stand more than 14 ft. high above the level of the rails.

417. *Q.*—Are locomotive boilers provided with a steam chest?

A.—The upper portion of the external fire box is usually formed into a steam chest, which is sometimes dome shaped, sometimes semicircular, and sometimes of a pyramidical form, and from this steam chest the steam is conducted away by an internal pipe to the cylinders; but in other cases an independent steam chest is set upon the barrel of the boiler, consisting of a plate iron cylinder, 20 inches in diameter, 2 feet high, and three eighths of an inch thick, with a domeshaped top, and with the seam welded and the edge turned over to form a flange of attachment to the boiler. The pyramidical dome, of the form employed in Stephenson's locomotives, presents a considerable extent of flat surface to the pressure of the steam, and this flat surface requires to be very strongly stayed with angle irons and tension rods; whereas the semiglobular dome of the kind employed in Bury's engines requires no staying whatever. Latterly, however, these domes over the fire box have been either much reduced in size or abandoned altogether.

418. *Q.*—Is any beneficial use made of the surplus steam of a locomotive?

A.—To save the steam which is formed when the engine is stationary, a pipe is usually fitted to the boiler, which on a cock being turned conducts the steam into the water in the tender, whereby the feed water is heated, and less fuel is subsequently required. This method of disposing of the surplus steam may be adopted when the locomotive is descending inclines, or on any occasion where more steam is produced than the engine can consume.

419. *Q.*—What means are provided to facilitate the inspection and cleaning of locomotive boilers?

A.—The man hole, or entrance into the boiler, consists of a circular or oval aperture of about 15 in. diameter, placed in Bury's locomotive at the apex of the dome, and in Stephenson's upon the front of the boiler, a few inches below the level of the rounded part; and the cover of the man hole in Bury's engine contains the safety valve seats. In whatever situation this man hole is placed, the surfaces of the ring encircling the hole, and of the internal part of the door or cover, should be accurately fitted together by scraping or grinding, so that they need only the interposition of a little red lead to make them quite tight when screwed together. Lead or canvas joints, if of any considerable thickness, will not long withstand the action of high pressure steam; and the whole of the joints about a locomotive should be such that they require nothing more than a little paint or putty, or a ring of wire gauze smeared with white or red lead to make them perfectly tight. There must be a mud hole opposite the edge of each water space, if the fire box be square, to enable the boiler to be easily cleaned out, and these holes are most conveniently closed by screwed plugs made slightly taper. A cock for emptying the boiler is usually fixed at the bottom of the fire box, and it should be so placed as to be accessible when the engine is at work, in order that the engine driver may blow off some water if necessary; but it must not be in such a position as to send the water blown off among the machinery, as it might carry sand or grit into the bearings, to their manifest injury.

420. *Q.*—Will you state the dimensions of the tube plate, and the means of securing the tubes in it?

A.—The tube plates are generally made from five eighths to three fourths of an inch thick, but seven eighths of an inch thick appears to be preferable, as when the plate is thick the holes will not be so liable to change their figure during the process of feruling the tubes: the distance between the tubes should never be made less than three fourths of an inch, and the holes should be slightly tapered so as to enable the tubes to hold the tube plates together. The tubes are secured in the tube plates by means of taper ferules driven into the ends of the tubes. The ferules are for the most part made of steel at the fire box end, and of wrought iron at the smoke box end, though ferules of malleable cast iron have in some cases been used with advantage: malleable cast iron ferules are almost as easily expanded when hammered cold upon a mandrel, as the common wrought iron ones are at a working heat. Spring steel, rolled with a feather edge, to facilitate its conversion into ferules, is supplied by some of the steel-makers of Sheffield, and it appears expedient to make use of steel thus prepared when steel ferules are employed. In cases where ferules are not employed, it may be advisable to set out the tube behind the tube plate by means of an expanding mandrel. There are various forms of this instrument. One form is that known as Prosser's expanding mandrel, in which there are six or eight segments, which are forced out by means of a hexagonal or octagonal wedge, which is forced forward by a screw. When the wedge is withdrawn, the segments collapse sufficiently to enable them to enter the tube, and there is an annular protuberance on the exterior circle of the segments, which protuberance, when the mandrel is put into the tube, just comes behind the inner edge of the tube plate. When the wedge is tightened up by the screw, the protuberance on the exterior of the segments composing the mandrel causes a corresponding bulge to take place in the tube, at the back of the tube plate, and the tube is thereby brought into more intimate contact with the tube plate than would otherwise be the case. There is a steel ring indented into the segments of Prosser's mandrel, to contract the segments when the central wedge is withdrawn. A more convenient form of the instrument, however, is obtained by placing the segments in a circular box, with one end projecting; and supporting each segment in the box by a tenon, which fits into a mortise in the cylindrical box. To expand the segments, a round tapered piece of steel, like a drift, is forced into a central hole, round which the segments are arranged. A piece of steel tube, also slit up to enable a central drift to expand it, answers very well; but the thickness of that part of the tube in which there requires to be spring enough to let the mandrel expand, requires to be sufficiently reduced to prevent the pieces from cracking when the central drift is driven in by a hammer. The drift is better when made with a globular head, so that it may be struck back by the hammer, as well as be driven in. An expanding mandrel, with a central drift, is more rapid in its operation than when the expansion is produced by means of a screw.

421. *Q.*—Will you explain the means that are adopted to regulate the admission of steam to the cylinders?

A.—In locomotives, the admission of the steam from the boiler to the cylinders is regulated by a valve called the regulator, which is generally placed immediately above the internal fire box, and is connected with two copper pipes;—one conducting steam from the highest point of the dome down to it, and the other conducting the steam that has passed through it along the boiler to the upper part of the smoke box. Regulators may be divided into two sorts, viz., those with sliding valves and steam ports, and those with conical valves and seats, of which the latter kind are the best. The former kind have for the most part consisted of a circular valve and face, with radial apertures, the valve resembling the outstretched wings of a butterfly, and being made to revolve on its central pivot by connecting links between its outer edges, or by its central spindle. In some of Stephenson's engines the regulator consists of a slide valve covering a port on the top of the valve chests. A rod passes from this valve through the smoke box below the boiler, and by means of a lever parallel to the starting lever, is brought up to the engineer's reach. Cocks were at first used as regulators, but were given up, as they were found liable to stick fast. A gridiron slide valve has been used by Stephenson, which consists of a perforated square moving upon a face with an equal number of holes. This plan of a valve gives, with a small movement, a large area of opening. In Bury's engines a sort of conical plug is used, which is withdrawn by turning the handle in front of the fire box: a spiral grove of a very large pitch is made in the valve spindle, in which fits a pin fixed to the boiler, and by turning the spindle an end motion is given to it, which either shuts or opens the steam passage according to the direction in which it is turned. The best regulator would probably be a valve of the equilibrium description, such as is used in the Cornish engine: there would be no friction in such a regulator, and it could be opened or shut with a small amount of force. Such valves, indeed, are now sometimes employed for regulators in locomotives.