internal furnaces opening into a large combustion-chamber about the middle of the length. From this a set of tubes distributed over nearly the whole water space extend to the back, where the uptake is situated.

136. The locomotive type of boiler has been successfully adap­ted to marine use by Mr Thornycroft aud others, especially for torpedo boats. This form gives much greater heating surface than others in proportion to its weight, and allows, especially when worked with forced draught, a large amount of power to be got from a small boiler. It is probable that, if any further rise is to occur in the steam pressure used in marine engines, comparable to that which has occurred during the last two or three years, the present normal marine boiler will give place to a form more nearly resembling the locomotive type.

137. Boilers are usually fed either by a feed-pump driven by the engine, or by a distinct auxiliary engine called a “ donkey,” or by an injector. The *injector,* invented by the late M. Giffard, and now very generally used on locomotive and other boilers, is illustrated in fig. 56. Steam enters from the boiler at A and blows through an annular orifice B, the size of which

is regulated by the handle C. The

feed-water flows in at D, and meeting

the steam at B causes it to condense.

This produces a vacuum at B, and

consequently the water rushes in with

great velocity, and streams down

through the combining nozzle I, its

velocity being augmented by the im­

pact of steam on the back of the

column. In the lower part of the

nozzle E the stream expands ; it there­

fore loses velocity, and, by a well-

known hydrodynamic principle, gains

pressure, until at the bottom its pres­

sure is so great that it enters the boiler

through a check-valve which opens

only in the direction of the stream.

The escape orifice F and the overflow

pipe G allow the injector to start into

action, by providing a channel through

which steam and water may escape be­

fore the stream acquires enough energy

to force its way into the boiler. The

opening for admitting water between

D and B is regulated by the wheel H.

The *exhaust-steam injector* works by

steam from the exhaust of non-con­

densing engines, instead of boiler

steam. The steam orifice is then

larger in proportion to the other parts,

and the steam supply more liberal. In *self-starting injectors* an arrangement is provided by which overflow will take place freely until the injector starts into action and then the openings are auto­matically adjusted to suit delivery into the boiler. One plan of doing this is to make the combining nozzle under the steam orifice in a piece which is free to slide in the outer casing. Until the injector starts it lies at some distance from the steam orifice, and allows free overflow ; but when the vacuum forms it rises, in conse­quence of pressure at the base. In self-adjusting injectors this rise of the combining nozzle is made use of to contract the water-way round the steam orifice. In another form of self-starting injector one side of the combining nozzle is in the form of a hinged flap, opening backwards to allow overflow, but closing up when a vacuum is formed and the injector starts into action.@@1 Weir’s *hydrokineter* for large marine boilers is another apparatus in which the principle of the injector is made use of, with the object of promoting circula­tion of the water during the time steam is being raised. It con­sists of a series of nozzles, with water-inlets between them, through which water is drawn by means of a central jet of steam supplied from a donkey boiler.

138. In stationary engine boilers the feed-water is frequently heated by the products of combustion before these reach the chimney, in what is virtually an extension of the boiler itself. Green’s economizer is a contrivance for this purpose, in which the water passes through tubes whose outer surface is exposed to the hot gases and kept clear of deposited soot by the continuous action of a mechanical scraper. In locomotives and other non- condensing engines a portion of the exhaust steam is frequently made use of to heat the feed-water. When an exhaust-steam injector is employed it serves the purpose of a feed-water heater as well as that of a feed-pump. Besides increasing the efficiency of the boiler by utilizing what would otherwise be waste heat, a feed-water heater has the advantage that by raising the tempera­ture of the water it removes air, and also, in the case of hard water, causes lime and other substances held in solution to be

deposited in the heater instead of being carried into the boiler, where they would form scale. In Weir’s feed-heater for marine engines the temperature of the feed-water is raised to about 200° Fahr. by injecting steam from the intermediate receiver.

139. In stationary and marine boilers the steam, after leaving the boiler, is frequently taken through a *separator,* the function of which is to separate the dry steam from particles of water held in suspension. Steam is led round a sharp corner, and the water particles thrown off by centrifugal force collect in a *trap* below, from which they are discharged by a pipe which is kept open so long as the trap contains water, but is closed by a valve at the foot when the trap is empty. Traps are also fitted in many cases to steam-pipes for the purpose of returning condensed water to the boiler.

140. To prevent corrosion in boilers it is very usual to introduce blocks of zinc in metallic connexion with the shell. These are set in the water space, preferably at places where corrosion has been found specially liable to occur. Their function is to set up a galvanic action, in which zinc plays the part of the negative element, and is dissolved while the metal of the shell is kept electro-positive. Otherwise there would be a tendency for difference of electric quality between different parts of the shell to set up galvanic actions between the parts themselves, by which some parts, being negative to others, would be attacked. The zinc raises the potential of the whole shell enough to make all parts positive.

141. Allusion has already been made to the system which is universal in locomotive boilers of forcing the draught by a blast of exhaust steam in the chimney. A jet of boiler steam is occasion­ally used in marine furnaces for the same purpose ; but of late years the system which has found most favour is to box in the stokehole and keep the air in it at a pressure of from 1 to 3 inches of water by the use of blowing fans. This system has been applied largely in naval practice, with the result that the power of the boiler is increased in the ratio of about 3 to 2, or even more, as compared with its power under chimney draught. The efficiency of the boiler is, in general, slightly but not very materially reduced. An ordi­nary marine boiler bums 16 to 20lb of coal per hour per square foot of grate with natural draught, and 30 lb or more with forced draught. In torpedo-boat boilers of the locomotive type the con­sumption has in some cases been forced to more than 100 lb.

In Mr Howden’s system of forced draught the stokehole is open, and air is supplied by a blowing fan to a reservoir formed by enclosing the ashpit and also to another reservoir from which it gets access to the grate above and through the fire-door. On its way to the reservoir the air is heated by passing across a part of the uptake in which the hot gases from the furnace are led through tubes. This method of restoring to the furnace what would other­wise be waste heat forms an interesting alternative to the method of restoring heat to the boiler by passing the hot gases through a feed-water heater ; it is in fact an application to boiler furnaces of the regenerative principle alluded to in chap. II.@@2

142. Many appliances have been devised for the mechanical sup­ply of coal to boiler furnaces, but these have hitherto taken the place of hand-firing to only a very limited extent. In Juckes’s furnace the fire-bars are in short lengths, jointed by pins to form a continuous chain or web, which rests on rollers and is caused to travel slowly in the direction of the furnace’s length by pin-wheels round which the web is carried at the front and back. Coal is allowed to drop continually on the travelling grate from a hopper in front of the furnace. A more usual form of mechanical stoker is a reciprocating shovel or ram, supplied from a coal-hopper, which throws or pushes a small quantity of coal into the fire at each stroke. Along with this devices are employed for making the grate self-cleansing, by giving alternate fire-bars a rocking or sliding motion through a limited range. In Mr Crampton’s dust-fuel fur­nace the coal is ground to powder and fed by rollers into a pipe from which it is blown into the furnace by an air-blast. The mixture of fuel and air is so intimate that the excess of air required for dilution is only one-fifth of the amount required for combustion.@@3 A similar advantage attends the use of gaseous fuel, and of liquid fuel that is blown into the furnace in the form of spray.

143. The use of liquid fuel for boilers has of late acquired con­siderable importance in connexion with the discovery of crude petroleum, in large quantity, at Baku on the Caspian Sea. The petroleum refuse which is left after distilling paraffin from the crude oil forms an exceedingly cheap fuel, with a calorific value per lb about one-third greater than that of coal. It has now super­seded coal in the steamers of the Caspian, and has been largely employed for locomotives in the south-eastern part of Bussia. The oil is injected in the form of spray near the foot of the fire-box by a steam jet arranged in such a way that air will be drawn into the furnace along with the petroleum. In the arrangement for burn­ing petroleum used in Russian locomotives by Mr T. Urquhart the flame impinges on a structure of fire-brick, built in the fire-box

@@@1 See papers in *Proc. Inst. Mech. Eng.,* 1860, 1866, 1884.

@@@2 The methods and results of these systems of forcing draught are described in papers read before the Institution of Naval Architects, April 1886.

@@@3 *Proc. Inst. Mech. Eng.,* 1869.