FLASH BOILERS

BY

LIEUTENANT-COMMANDER J. D. RICHARD, R.N., A.M.I.MECH.E.

Parts of this article are contained in a wider article, by the same Author, concurrently being published in Light Steam Power *and permission of the Editor to reproduce these parts is acknowledged.*

'Get the boiler hot, then put some water in it when you want steam'—so a steam car driver was recently heard to remark as he prepared to move off by working the hand feed pump, after the fire had been in full blast for some minutes on an empty boiler; and as he pumped, 500 lb/sq in. appeared in a few seconds. This is quite normal practice with flash boilers, which will stand treatment that would be downright cruelty to any other type of boiler.

General Description

A flash boiler, or steam generator as some diehards would have it termed, is little more than a continuous tube, some hundreds of feet long, wrapped round a burner and appropriately cased and lagged. Water is fed in at one end, and superheated steam comes out at the other. There is no magic in the term 'flash'—water is not suddenly converted into steam on arrival at a

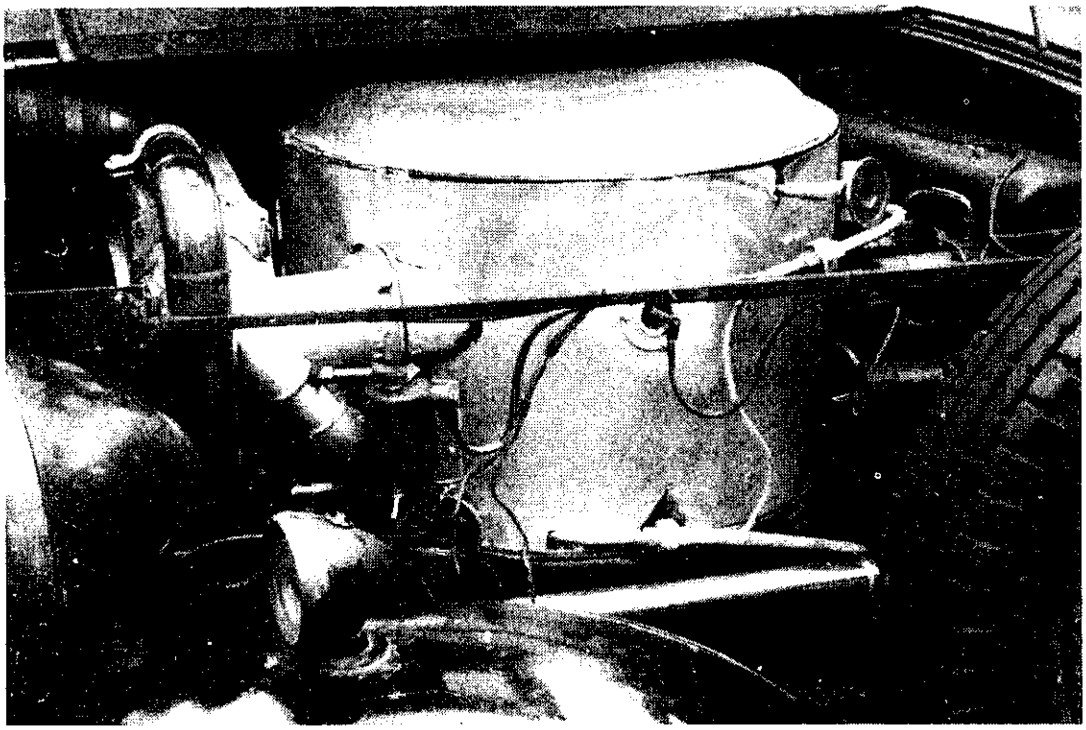

FIG. 1—A FLASH BOILER INSTALLATION
Left to right: blower (partly hidden by exhaust steam pipe), carburettor, thermostat switch, sparking plug, normalizer feed inlet, fuel pumps

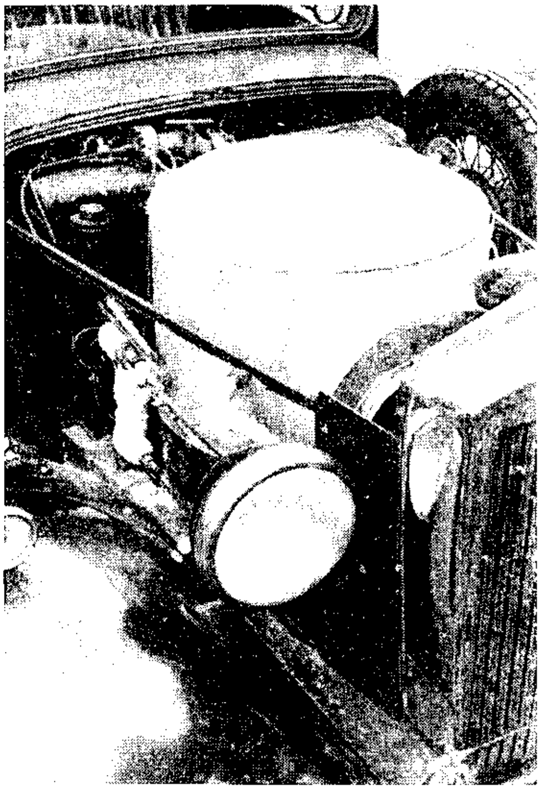

FIG. 2 A FLASH BOILER INSTALLATION SHOWING BLOWER (BETWEEN BOILER AND RADIATOR), THROTTLE (ON LEFT OF PICTURE), PRESSURE CONTROL UNIT (AT TOP)

particular expansion space or hot spot ; though it is true that a limited quantity of steam can be generated unusually quickly on increasing the feed supply after the boiler has been allowed to get hot while on light load. The process of steam generation is the ordinary one of gradual addition, along the tube length, of sensible heat, latent heat and superheat the successive portions of the single tube taking the roles of economizer, generator and superheater.

The tube banks consist of either spiral coils as in an evaporator, or zig-zag grids ; they are normally made separately and connected end to end by welding. Great variation is possible in the pattern of the connections, according to whether the particular bee in the designer's bonnet is optimum utilization of heating surface, avoidance of tube overheating, retention of water in the right place during periods of light load (for quick recovery), or what. For example, in one type (fired from below) the course of the water and steam is through the bottom coil, top coil, second from bottom, second from top, and so on, with outlet from the middle. In another type the water passes first through the two coils nearest the fire, then goes to the outlet end and gradually works back towards the fire. Another pattern will be described in more detail later.

Application

The limitations on the applications of flash boilers are:

(*a*) Their size—their advantages over other boilers show best in small sizes

(*b*) The requirements (if their ease of control is to be fully realized) for light oil firing (petrol, paraffin or Diesel, paraffin being most usual) and for an electrical supply for controls and auxiliaries

(*c*) Their absolute dependence on reliable auxiliaries. They could not, for example, act as dockside donkey boilers unless a revolution took place in the design and maintenance of the feed pumps normally met the situation.

It is perhaps these considerations that have caused the application of flash boilers to be restricted almost solely to cars, where conditions are right for them and where lightness and quick steam raising are important. The majority of steam cars built since 1905 have had this type of boiler, working at pressures between 500 and 1,500 lb/sq in. A notable exception is the Stanley, which stuck to its remarkable fire-tube boiler until it went out of production in the early 1920's.

Advantages

As compared to a capacity boiler, a flash boiler has much to commend it for safety, lack of maintenance requirements, and ease of manufacture and repair. Insurance is not compulsory, provided the tubing is all under 1 in. dia. There is no such thing as boiler cleaning, and the quality of the feed water is not important. There is no scaling up, as the high steam and water velocities that occur give little chance of any deposit sticking ; and, on the once-through principle, what goes in must come out. With a reciprocating engine and condenser, there is always plenty of oil in the feed, but this does not seem to matter: it goes through the boiler all right, as shown by the mess produced where any leak from the main steam line impinges, and it coats the interior of the tube and protects it from corrosion, which helps to account for the long life of these boilers. Several 50-year-old examples are still in service, in spite of the fact that, being in cars, they are most unlikely to have been always properly protected and preserved.

Detailed Description

Most of the experience to be related has been gained with a Doble type boiler, of design dating from the 1930's, which will be described. This particular boiler is a big one of its kind, being saddled with a heavy car and a Stanley engine, a type notorious for eating steam. The boiler weighs between three and four cwt, and generates between 600 and 800 lb of steam per hour at 800 lb/sq in. and 750 degrees F. The steam conditions are dictated by what the engine will take ; the same boiler would do for at least 1,200 lb/sq in. and 900 degrees F., except that some of the union connections on it, which are of a type meant for 250 lb/sq in., might have to be changed.

FIGS. 1 and 2 show the external arrangement. The dimensions outside the cleading are 24 in. dia. × 37 in. high.

FIG. 3 shows the boiler in section. The casing, which forms the main structure, is made in two halves with a horizontal joint at about mid-height. The top half is mainly empty space comprising the combustion chamber, which has a heat resisting steel lining, some tube surrounding it, and a tangential flame entry. The lower half is full of horizontal spiral pancake coils. The flue gas outlet is

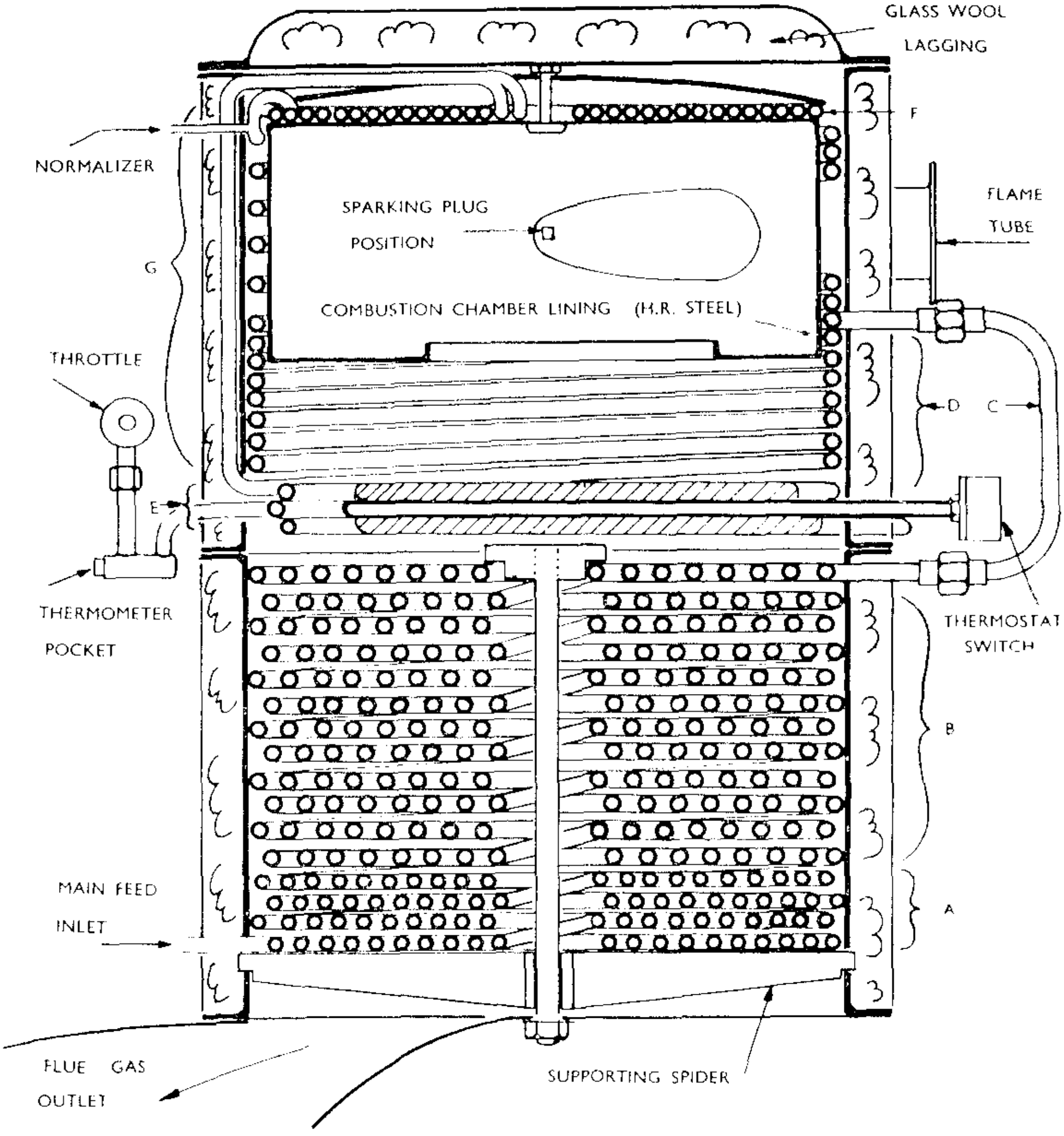

FIG. 3—SECTION THROUGH BOILER

at the bottom, with no exhaust pipe or duct.

The feed flow is in at the bottom, thence upwards coil by coil. The first four coils (A) are $\frac{1}{2}$ in. O.D. tube; the next twelve (B) are $\frac{11}{16}$ in. These sixteen coils are welded end to end to form a continuous tube, and comprise the main bank of heating surface; the top coil of this bank constitutes the fire-row tubes.

An external pipe connection (C) takes the steam, by now mildly superheated, to the top section of the boiler. The steam makes four turns (D) round the combustion chamber, and makes a pass through the thermostat (E), which will be described later; thence to a close-coiled pancake (F) on top of the combustion chamber.

At this point occurs that mysterious secondary feed inlet called the 'normalizer', to which a fraction of the feed is admitted in parallel with the main inlet. One is told that this is a usual fitting on modern flash boilers, and that it is something to do with preventing oscillations of steam temperature on account of the long time taken for a change in the main feed supply to be felt at the thermostat. In fact, it makes no difference what setting is put on the normalizer regulating valve, or even if it is shut right off. At the risk of uttering a heresy, this connection must be classed with ‘ the strange things they told me at college ’. Or, seeing that the early flash boilers worked with no normalizer, perhaps the feeding of such a boiler is among the many bits of engineering practice that acquired the status of problems when servo theory was invented. Anyway, the clack valve on the normalizer connection makes a comforting little noise when the boiler is feeding, so it earns its keep.

After this, the steam makes about ten more turns (G) round the combustion chamber, another pass through the thermostat, and emerges from the boiler casing to the thermometer pocket and throttle.

The tubing in the top half of the boiler is $\frac{11}{16}$ in. dia. (except the top pancake, which for reasons unknown is two $\frac{1}{2}$ in. dia. tubes in parallel) and is all welded.

The tube material is mild steel throughout. The heating surface is 101 sq. ft, and the tube length 625 ft.

Mountings and Fittings

A normal outfit of pressure fittings on a flash boiler would be, simply :

Main feed inlet (with non-return valve)
Normalizer feed inlet (with non-return valve)
Steam connection to pressure gauge and automatic control
Thermometer pocket
Stop or throttle valve.

A safety valve and a saturated steam offtake for a donkey pump may also be fitted. There is no need for vents, drains, blowdowns, level gauges, or handholes.

It is generally held in the steam car world that the only spanners that will make and unmake reliable pipe joints are a welding torch and a hacksaw ; but on the boiler described, all external pipe connections are screwed unions, and they have given no trouble at all, even the one at the inlet to the throttle, which has to take the full working conditions of 800 lb/sq in. and 750 degrees F., with an occasional accidental excursion to 1,000 degrees F.

In some designs of boiler, the throttle comes before the superheater. This is kinder to the components it relieves the throttle valve of some of the temperature, and the superheater tube of some of the pressure. It is not all jam : if the superheater gets water in it, it acts as a boiler in its own right and the throttle ceases to control the engine. This can be quite exciting. However, this particular carnival really goes with capacity boilers, and occurs when they prime. Flash boilers, having no steam-water separation process, are immune from priming ; they can only give carry-over of water if something goes drastically wrong with the temperature control.

If a safety valve is fitted at all, it usually works by *letting the water out*, which is much the quickest way of reducing pressure. There is a bit of a trick here. An engine-driven feed pump, working against the inertia of the water in a single tube several hundred feet long, produces pressure pulses of many hundred lb/sq. in. when at high speed, though the steam pressure at the boiler outlet may be steady and normal. A plain safety valve fitted to the feed inlet would, therefore, blow at every stroke of the pump. To get over this, a water discharge valve fitted at this point is arranged to be opened at blow-off pressure, by steam from the boiler outlet acting on a spring-loaded piston or diaphragm.

Control Systems and Auxiliaries

There is, of course, no water level in a flash boiler ; and the firing and feeding are regulated according to the steam temperature and pressure.

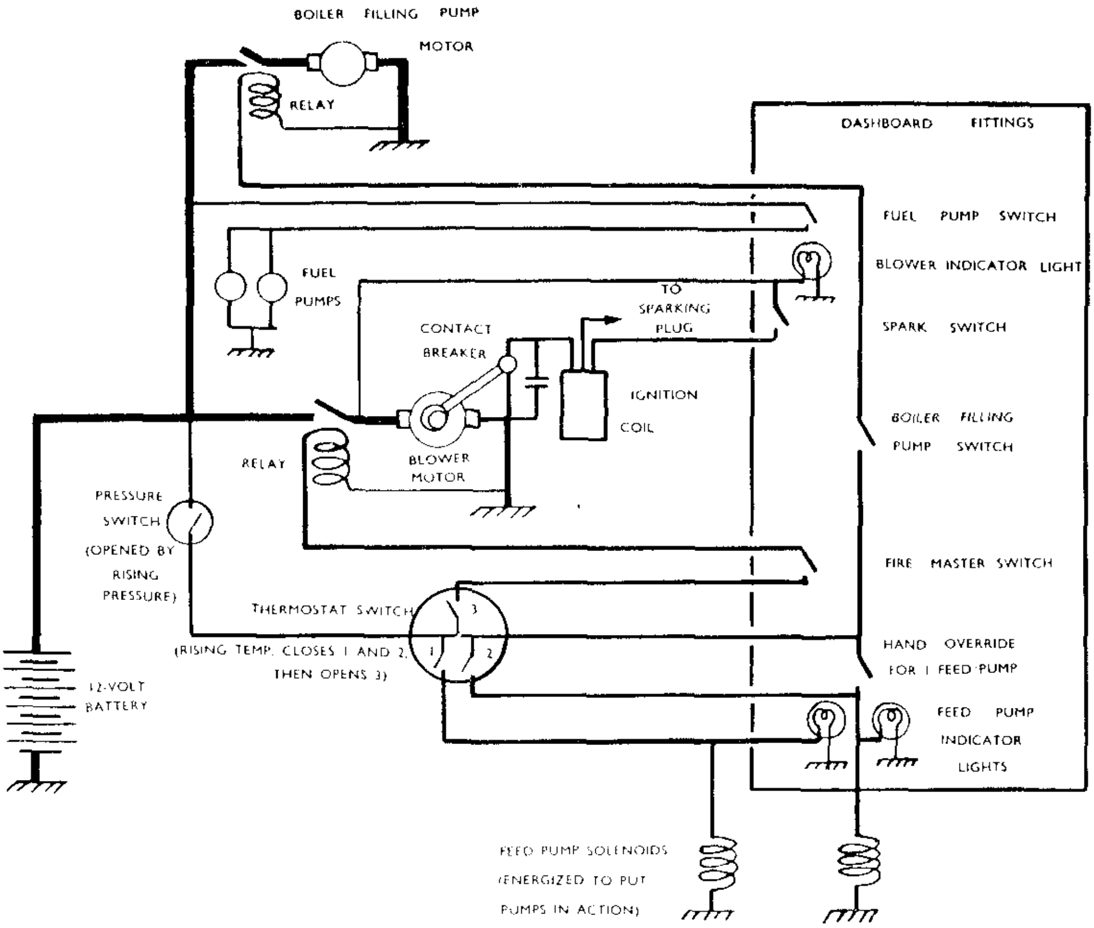

FIG. 4 AUXILIARY CONTROL CIRCUITS

Several methods of control are possible, the choice depending largely on the type of burner and auxiliaries.

The Serpollet cars, in the early 1900's, had a vaporizing burner (like a large Primus or blow lamp), and natural draught, which allowed a wide range of fire output to be obtained simply by regulating the fuel supply. A donkey engine pumped feed and fuel in a fixed ratio (about 6 to 1) and the speed of the donkey was regulated by hand to keep the steam pressure right, letting the temperature find itself. No temperature indicator was fitted. When adjusting after repairs, the correct setting of the pump delivery ratio was found by running the fire at full output and reducing the feed pump stroke until the steam outlet pipe from the boiler began to glow, then increasing it again ' a wee bit '.

This system is quite convenient to drive with ; its disadvantage is the vaporizing burner, requiring to be preheated with methylated spirit or bottled gas, before steam can be raised.

In another early system, the Turner-Miesse, the fire was kept at one of two constant outputs—full rate for country and half rate for town—and the steam output was regulated solely by the amount of feed admitted. The feed pump was engine-driven, with a hand-controlled by-pass, and there was a hand feed pump for starting off. After descending a long hill, with full fire on and no feed at all, the boiler would be red hot, which was just right to give a smart climb up the other side. Fortunately, the iron-steam reaction had not been invented in those days.

A typical modern plant has a pressure atomizing burner, an electric forced-draught blower, electric ignition, a steam donkey pump delivering feed and fuel, and on-off control of the feed and fire, actuated automatically by the steam temperature and pressure. The feed control acts on a solenoid valve in the steam line to the pump ; the fire control switches the blower motor on or off, at the same time operating a solenoid valve in the pressure fuel line to the burner. An air-loaded accumulator looks after the supply of fuel when the pump is not running, as when lighting up and when the automatics demand fire but not feed.

A paraffin spray from a good atomizer will light from a sparking plug even when cold, so on-off control presents no difficulty. The plug is arranged to be sparking all the time the blower is running.

With such an outfit, steam can be raised by the turn of a switch ; and no attention is required during running.

The boiler described has automatic temperature and pressure controls in line with modern practice, allied to the outmoded system of axle-driven feed pumps, and to a carburettor type burner. The feed pumps have solenoid control that works by lifting the suction valves. The carburettor allows of a simpler system than a pressure atomizer, in that it requires no high-pressure fuel pump or solenoid fuel valve, but it gives very poor fuel-air mixing, resulting in excessive fuel consumption and the inability to light from the sparking plug on paraffin when the combustion chamber is cold. A small supply of petrol is required for lighting up.

The automatics, in spite of some rather bogus engineering perpetrated by past experimenters, are perfectly reliable. A stranger, knowing nothing about steam, can be put in the car, told which pedal is for go and which for stop, and left to drive it in the confidence that the boiler will not let him down or blow him up. The reliability is such that the safety valve once fitted has been removed, as an unnecessary appendage that merely interfered with pressure testing.

The automatics are connected, as shown in FIG. 4, to the solenoids controlling the fire and the main feed pumps, each of which is brought into operation by energizing (rather than breaking) its respective circuit. This is the fail-safe method of connection—obviously so for the fire (lack of current puts the fire out); not so obviously so for the feed pumps. With a flash boiler, it turns out to be safer to leave undone the feeding that ought to be done than to do the feeding that ought not to be done. In the former case, there is the excess temperature cut-out to deal with the fire ; or, if steam is being used at all, the pressure will soon disappear, fire or no fire, and then there is no danger, whereas, in the latter case, there is danger of generating excessive pressure, or of damaging the engine by water carry-over. So the principle is to stop feeding when in doubt.

Feed pump control circuits arranged in accordance with this principle (current on to cut pump in) conveniently switch themselves off as the boiler cools down, and it is not necessary to have an extra hand switch (and to remember to use it) to conserve the battery when shut down. For once the law of cussedness has not operated.

Pressure Control

This is a spring-loaded diaphragm, opening a switch at working steam pressure to cut out the fire and feed pumps ; they come in again on a fall of

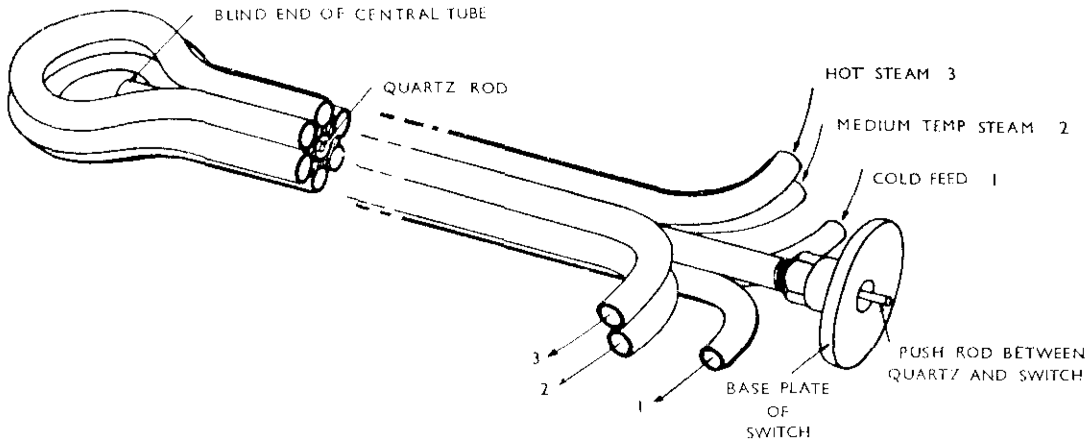

FIG. 5—THERMOSTAT TUBE ASSEMBLY

about 80 lb/sq in. When driving on the level at 30 m.p.h. they will be in and out about four times a minute.

The reason for cutting out the feed pumps, as well as the fire, is illustrated by the progress of one of the early attempts to raise steam in this boiler. The electric auxiliary feed pump that was then fitted had been run for some time, and the boiler was thought to have plenty of water in it ; but repeated applications of the fire, for short periods in the course of an hour or so, produced no pressure. It was then noticed that the boiler casing, outside the tubes surrounding the combustion chamber, was red hot. At that stage the auxiliary feed pump suddenly became effective ; water entered the boiler for the first time, and 700 lb pressure appeared in under ten seconds. The main engine was started, to take the steam away, and it spun merrily for about twenty *minutes with no fire at all and the main feed pumps cutting in and out under* the automatic pressure control, the pressure remaining at 650–700 lb, which was at that time the setting on the automatic. If the feed pumps had not been cut out by the pressure control, that boiler would have burst.

That incident also showed that there is quite a lot of thermal capacity in a flash boiler—more than is generally supposed. One is often asked whether a car with such a boiler is controlled by regulating the fire, rather than throttling the steam ; but this would not do. Such a method was indeed practicable with the Serpollet system previously described—one could open the throttle wide and ' drive on the donkey ', but only when settled on a long run with a clear road. The time lag is far too great for ordinary driving. As an illustration, this car once ran out of fuel two miles from home, but got back before the steam disappeared ; so turning the fire off is not a very effective means of easing down.

Thermostat

The sensing element of the temperature control is illustrated in FIG. 5. It consists of three steel hairpin tubes having their straight portions, which are about 15 in. long, bunched together with a further straight tube, open at one end and closed at the other, in the centre of the bunch. The whole bunch is welded together in a solid mass. Relative expansion, between the central tube and a quartz rod inside it, operates the switch.

The three hairpin tubes carry respectively cold feed, steam partially superheated, and steam at its final temperature ; this array of tubes lies across the bottom of the combustion chamber of the boiler, and is thus also subject to direct heating from the fire. The reasons for this rather complex arrangement are not clear, and one would imagine that at least the intermediate steam element could be left out.

The temperature switch is carried on the open end of the central tube, outside the boiler casing. Its functions are, as temperature rises, to cut in first one feed pump, then the other, and finally to cut out the fire. The latter function should not normally be called into play. It is an emergency protection in case of failure of the feed pumps to deliver, loss of water when stationary, or raising steam with insufficient water in the boiler. Until the main feed pumps were induced to work regularly, this excess temperature cut-out had to do its stuff quite often, and proved itself a real necessity. Now that the pumps are reliable, it is called on much less frequently. It should have prevented the boiler becoming red hot in the incident described under 'Pressure Control'; but at that stage its proper setting had not been found.

The temperature setting of the thermostat as a whole is adjustable, and the interval between the cutting in of the first and second feed pumps can be adjusted independently. This interval needs to be set fairly wide—50 degrees to 100 degrees F.—to give stable temperature control. If the two pumps are set too close to each other in temperature, a bit of a hunt will sometimes set in—for a period of several minutes both pumps will come in with the fire each time the pressure switch is made, then for a like period neither will come in.

Car speed has quite an effect on the accuracy of temperature control, and swings of 100 degrees F. or so can take place under conditions of varying speed. This is because the feed pumps are axle-driven, so that their delivery rate varies with the speed. To get the right quantity of feed under all conditions, a constant-speed feed pump would be more suitable. This may seem a paradox until it is remembered that the feed pumps are cut in and out, simultaneously with the fire, by the pressure switch, and the fire works at constant rate; only the length of time for which it cuts in being variable with the power. To match it, the feed pumps ought to work at a constant rate too, and the temperature control would only have to trim that rate, instead of being on the ball all the time coping with whatever feeding rate happens to be current. The more modern system of a donkey-driven feed pump has an advantage here.

The axle-driven pump system works all right, its slight disadvantage being that, owing to the temperature swings that take place, one dare not run quite as close as one would wish to the maximum temperature deemed safe for the engine, so a bit of performance is lost.

The performance of a given engine is most markedly dependent on steam temperature, and the ready adjustment of superheat that a flash boiler affords, gives a striking demonstration of this. The engine is a different animal with steam at 800 degrees as opposed to 700 degrees. Being a piston valve engine, 850 degrees is its limit. The poppet-valve engines fitted in some cars will allow the use of steam up to 1,000 degrees.

Raising Steam

The boiler is lit up by simply switching on the fuel pumps (ordinary automobile ones) and the blower. Ignition takes place within two or three seconds, and the fire sets up its characteristic deep roar a sound described by the neighbours as being positively evil, like the prelude to an earthquake. The fuel cock is then switched from petrol to paraffin, where it remains until the next prolonged shut-down is foreseen. Once warm, the fire will relight on paraffin from the sparking plug as required by the auto control, or on lighting up again after a shut-down of up to three hours.

Flash boilers are quick steam raisers, but the claims of one minute or so, made for some types, cannot be confirmed. This boiler can raise full pressure in three minutes, when all is going well, but there are often snags, and it is as well to allow ten minutes for this operation.

The usual trouble is the wrong quantity of water in the boiler. The amount remaining after a shut-down period is indeterminate. Leaky valves let it out while pressure remains ; it escapes either as steam past the throttle, or as water back past the feed check valves, and there is generally little left after an hour or so. On cooling right down, the boiler will sometimes suck itself full of water again.

If it is nearly full, pressure comes up very quickly, perhaps within a minute of turning the fire on ; it is then necessary to blow steam to waste to keep the pressure down, and hence the fire in, until a bit of temperature appears, as if one tried to drive off directly, the steam would disappear at once.

If there is a shortage of water in the boiler, it is not so easy. The symptoms are a lack of pressure after two minutes or so firing ; the lighting of two indicator lamps, showing that the thermostat is trying to cut in the feed pumps, which, being axle-driven, are not running at this stage ; and finally, the fire cutting out on excess temperature, with perhaps only 200 lb of steam—not enough to move the car, with the engine cold. The remedy, of course, is pumping ; at present this must be done either with a hand auxiliary feed pump or by jacking up a back wheel and running the engine, so as to bring the main pumps into service. The latter method is troublesome, but carries the compensation that the engine gets warmed up, leading to a better eventual getaway. With no clutch or gearbox, the engine cannot be warmed up without moving the wheels.

A steam auxiliary feed pump is to be fitted. When this is available, raising steam will become a precise and predictable operation.

The time taken to get started, often quoted as a disadvantage of steam cars, only applies to starting from cold. After shutting down, the engine remains warm for several hours and steam pressure may remain in the boiler for an hour or more, and comes up within a matter of seconds when the fire is turned on. After a halt of half an hour or less, one can drive off instantly by simply pressing the accelerator, and switch the fire on when under way—while the I.C. driver is still going through the ritual of ignition switch, electric starter, clutch, and gear lever and, even in these modern times, making a noise.

Shutting Down

At brief halts, it is only necessary to switch off the blower. It is not mechanically necessary even to do that, but leaving a car unattended, with the fire cutting in automatically for a few seconds every two minutes or so to keep the pressure up, is presumably an equivalent offence to leaving a petrol car with the engine running.

When a halt of some hours is foreseen, the routine is to change over to petrol in preparation for the next start, and a little later, when about a mile from home, switch the fire off. Steam pressure and temperature soon fall, and the thermostat tries to cut out the feed pumps. An overriding hand switch allows one feed pump to be kept on ; this slows the fall in pressure, at the expense of temperature. After a mile or so, steam is down to 200 lb saturated, which (with the engine hot) is enough for parking manœuvres ; and there is a good chance of enough water being left in the boiler for the next start.

When the steam auxiliary feed pump is fitted, it will be left jogging as the boiler cools down, and the water will always be there when it is required.

Maintenance

There is practically no routine maintenance. With paraffin firing, no external cleaning is required and, as previously mentioned, internal cleaning is both superfluous and impossible. Stripping down, up to a point, is quite simple : the top half of the boiler, containing the combustion chamber, superheater, and thermostat, lifts off ; it weighs about 100 lb. The main bank of spiral coils then lifts out of the bottom half casing ; it weighs about 160 lb. Further dismantling is a hacksaw and welding job.

Defects

One boiler tube failure has been experienced, following on the early running without the automatics or the feed pumps in proper order. The failure took the form of a bulge, with cracks, in the top coil of the main tube bank, and the symptoms were a hiss that could be heard when driving slowly, and vapour appearing round the bonnet when stationary. As the top coil as a whole looked a bit old-fashioned, it was renewed. This merely entailed winding a new coil—a miniature single-start spiral evaporator coil in mild steel—and welding it on. Not by any means a difficult job ; and that was the biggest repair job that could occur with this type of boiler.

Even a complete tube fracture could not have serious consequences. There is only a small quantity of steam to be released, and most of it would have to come a very long way to get to the fracture, so the ferocity of the blow would be reduced considerably and nothing would be harmed outside the boiler casing. That is why there is no compulsory insurance with this type of boiler.

Conclusion

To sum up, a flash boiler is a remarkably compact, safe, and easily run means of producing steam. It makes certain demands on its auxiliaries and controls, and speedily reflects any temperament on their part ; but if properly served by these things, it will produce steam to order, at any reasonable temperature and pressure, without much delay and without requiring a lot of the paraphernalia that surrounds a normal boiler.