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G.W.R. Mechanics' Institution.

SWINDON ENGINEERING SOCIETY.

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Chairman – Mr. W. A. Stanier, M.I.Mech.E.

"SMOKE-BOX DESIGN,"

By

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The chief use of the smokebox is to act as a chamber through which the exhaust steam may be passed to create a partial vacuum, by means of a suitable arrangement of blast pipe and chimney, and so induce the necessary draught on the fire. The box itself is made of steel plate

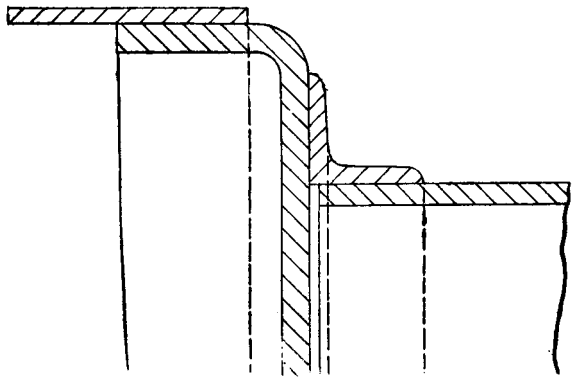

Fig. 1.

$\frac{3}{8}''$ to $\frac{1}{2}''$ thick, and in earlier practice was lined with an inner shell of $\frac{1}{8}''$ plate, standing away from the outer casing about $1''$. It was intended to act as a protection for the outer plate, but in many cases got eaten away, allowing ash to accumulate between the plates, sometimes with bad results.

One method of attaching the smokebox to the boiler is to rivet it to

the tube plate, which is flanged for the purpose. The tube plate is made larger in diameter than the boiler barrel and connected to it by an angle iron (Fig. 1). In this case the tube plate is not completely circular, being lengthened at the bottom for the purpose of attachment to the cylinder casting. The sides of the smokebox are brought down and bolted to the cylinder, as in Fig. 2. The front end of the smokebox is formed by means of a flat plate, secured to the sides by an angle iron (Fig. 3). This arrangement is efficient, but occasionally gives trouble

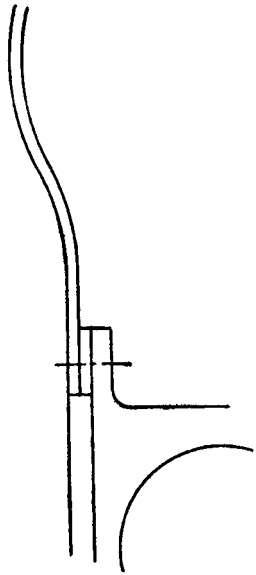

FIG. 2.

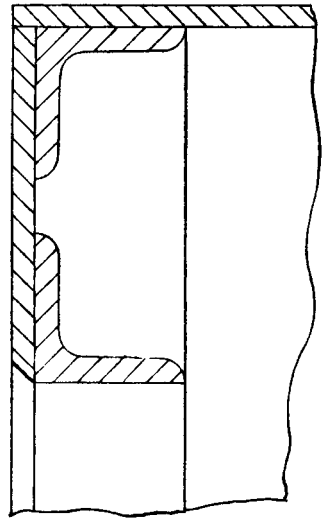

FIG. 3.

through air being admitted at the joints, resulting in heated plates. In order to protect the joints from the action of gases and hot ashes, a lining of firebrick is often introduced.

In more modern practice the boiler barrel is allowed to project four or five inches beyond the tubeplate, which is flanged and let into the barrel. In order that the smokebox shall be flush with the cleating, an iron ring is placed between the projection of the boiler barrel and the smokebox plate, and rivets are passed through the three (Fig. 4).

The smokebox, being circular in shape, is rolled from one plate and joined at the top by a butt strip. It rests in a saddle cast on the

cylinders or a saddle built up of plates secured to the cylinders as previously described. In the latter case the box is lined inside at the bottom with a plate, fitting closely round the blast pipe and steam

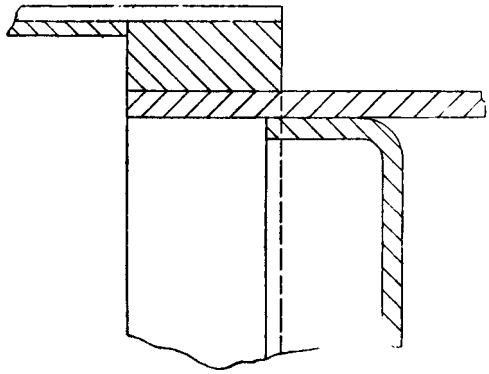

FIG. 4.

pipes, to confine the ashes to the box proper and to facilitate the clearing of the box.

This design of smokebox has also proved a good one, although cases do occasionally arise of engines drawing air at the joints. When cast with the cylinders, the saddle is machined to the correct radius when the cylinders are bolted together. The smokebox is secured to the

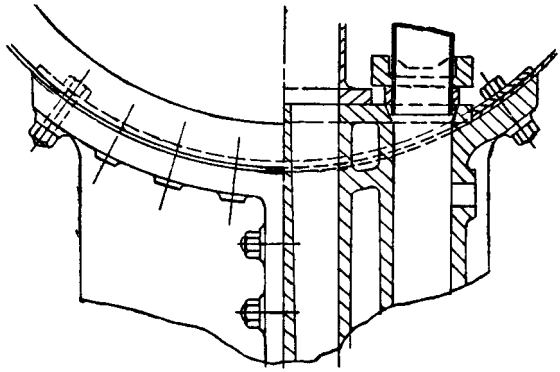

FIG. 5.

saddle with turned bolts (Fig. 5). This is a very good form of joint, probably owing to its rigidity, which is an important item when it is remembered that the firebox end of the boiler is comparatively loose in

the frames. A $\frac{1}{2}''$ liner is fitted round the bottom of the box, and in order to protect the bottom of the tubeplate from corrosive action a casting, termed a tubeplate protector, is fitted.

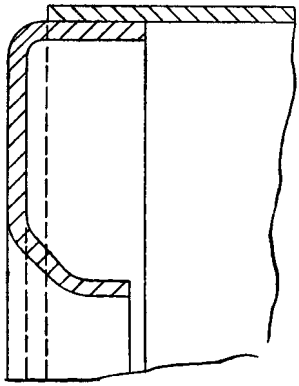

Fig. 6.

The front of the smokebox is a circular flanged plate, the opening in it for the door being also flanged in such a way as to provide a seating for the door (Fig. 6). This end is good in appearance and is cheap, the two flanges being made together, and only one riveting operation is required.

The smokebox door is an important item needing good designing and fitting, trouble often being caused through the doors drawing air and so being heated.

There is a fair amount of variety in the shapes of doors, and Figs. 7 and 8 show two in common use.

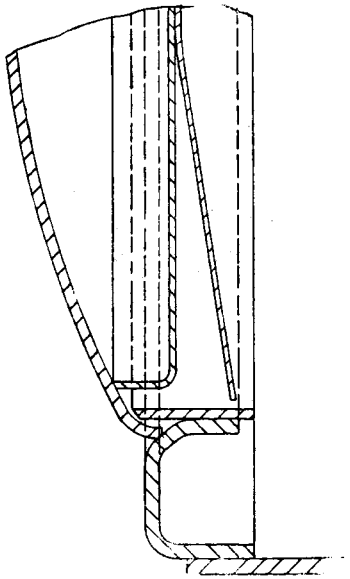

Fig. 7.

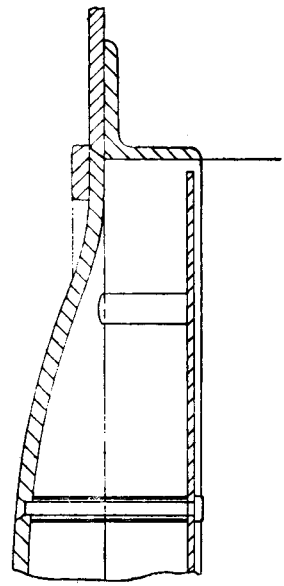

Fig. 8.

The usual means of securing the door is by means of a bolt or " dart " passing through a bar stretched across the inside of the box and resting

on two supports on either side. This bar is not fixed in any way, and can readily be lifted out in order to gain access to the box.

Some engines are fitted with clips at intervals round the outside edge of the door in order to tighten the joint.

In designing the blast pipe, care should be taken to give the exhaust steam an easy passage, avoiding short bends and sudden contractions, so that the steam may only be throttled where absolutely necessary—*i.e.*, at the orifice of the pipe.

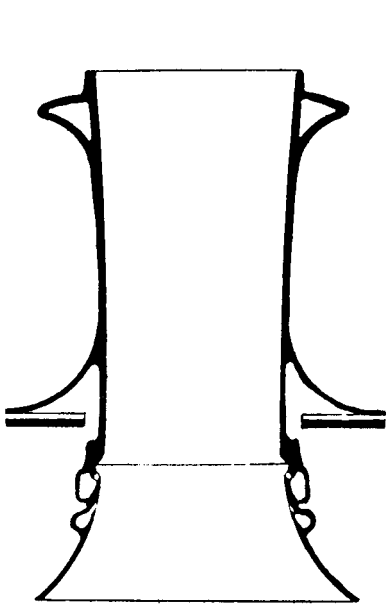

FIG. 9.

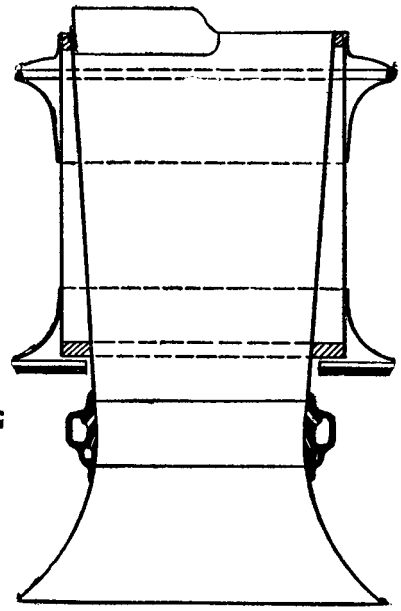

FIG. 10.

The blast pipe is usually of cast iron $\frac{3}{8}''$ thick, a few being made of copper with gunmetal flanges.

It is good practice to make the top part of the blast pipe detachable, so that it may be changed if necessary for another top with an orifice slightly larger or smaller.

The necessary draught for the fire is effected by contracting the exhaust nozzle, the strength of jet being inversely proportional to the diameter of the blast pipe tip. There are two reasons for keeping the orifice as large as possible consistent with good steaming, the result of throttling the exhaust being to cause an increase of back pressure in the

cylinders, and also with too heavy a blast there is a tendency to lift the fire in the firebox. The chief factors in determining the diameter of the blast pipe tip are boiler pressure, grate area and cylinder volume.

Goss and others have made exhaustive experiments in order to arrive, at conclusions relative to the most suitable diameter of blast pipe tip, chimney, etc. The information thus obtained is interesting and of value, but it is fairly evident, from a long series of experiments carried out at Swindon, that it is impossible to lay down any definite rules. Conditions such as type of engine, work required for, class of coal, etc.

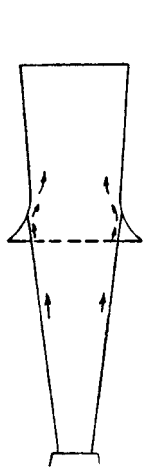

FIG. 11.

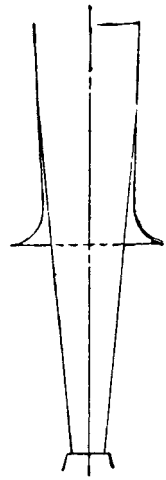

FIG. 12.

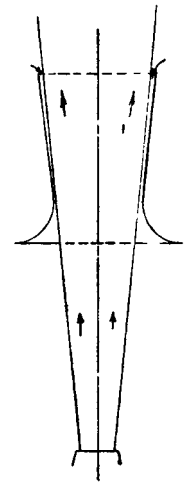

FIG. 13.

making formulæ practically useless, it being found necessary to deal with each class of engine separately.

Chimneys are made of cast iron (fig. 9.) or are built up of steel plate. The present G.W.R. practice is a chimney built up of an outer casing of $\frac{1}{8}''$ steel plate, with a copper sheathing round the top, and an inner shell of $\frac{3}{16}''$ steel plate attached to the outer shell by iron rings placed between them (Fig. 10). The inner shell is allowed to project through into the smokebox, and the blower and ejector ring bolted to it. Below this the cone or petticoat pipe, which is used to assist the gases towards the chimney, is fastened on.

In order to obtain the necessary vacuum in the smokebox it is necessary that the jet shall fill the chimney. The point at which the jet is

supposed to strike the chimney is known as the choke, and is taken as being the narrowest part, and varies in diameter from 1′ 0″ on small engines to 1′ 3″ on larger engines.

Whether the jet actually strikes at this point depends on the distance from the top of the blast pipe to the choke. If the blast pipe is too low, there is a tendency for the jet to strike the chimney below the narrowest part, so that the steam contracts again, having a baffling effect on the jet, tending also to prevent a free flow for the smokebox gases (Fig. 11).

The effect of pitching the blast pipe too high depends to some extent on the length and taper of the chimney. With a long chimney and a gradual taper it will not do much harm if the jet strikes the chimney above the choke (Fig. 12).

However, where the chimney is short and the taper fairly considerable,

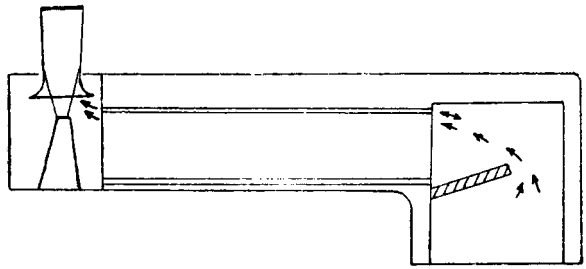

Fig. 14.

there is a possibility that the jet may not strike the chimney at all, but go straight through (Fig. 13).

If the jet strikes the chimney at the choke, and fills it sufficiently to induce the required draught, it is not necessary to throttle the steam any further, and therefore it seems reasonable to make the chimney of greater diameter at the top than at the choke. This is contrary to earlier practice, which was to make the top 1″ less in diameter than the bottom. However, in this case the blast pipe used to be carried up very high, the jet probably striking the chimney near the top. A good reason for this belief is furnished by the deposit which is found at the base of the chimney.

The height of the blast pipe, relative to the boiler centre, is an important factor in determining the efficiency of the smokebox. The two circumstances which cause a large part of the work of the tubes to

be done by the upper ones are their proximity to the jet and the use of a long brick arch, which has a tendency to protect the lower tubes (Fig. 14). This is undesirable, as full use is not made of the available flue area, and also it is beneficial to use the bottom tubes well, in order to increase the circulation in the boiler.

With these objects in view, the modern tendency is to keep the blast pipe low and also to increase the distance from the tubeplate, thus giving an even distribution over the tubes and a more direct passage for the gases. The blast pipe must not be too low, or it may result in ashes being drawn down into the cylinders when the engine is drifting.

It is evident that with a box of small cubic capacity the effect of each beat or buff is to create a large vacuum suddenly, the result being that the draw on the fire is fierce and intermittent. If, however, the box be enlarged, the effect of each beat is not so pronounced, the box acting as a kind of reservoir, thus making a steadier draught, which is desirable.

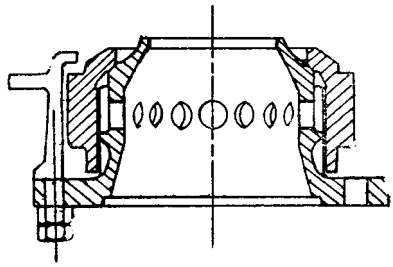

Fig. 14.

With the increase in boiler pressure, size of firebox, &c., the strength of the jet has increased, making the need for a larger box more pronounced.

It has long been recognised that the blast pipe tip should be variable according to the work the engine is doing. With the idea of obtaining a variable blast pipe tip, a number of ingenious devices have been tried, but while they work well for a time, they are usually found to be clogged up when most wanted. It is impossible to use any very delicate mechanism in the smokebox.

Several devices have been used to sharpen the blast, consisting of a ring having a V-shaped bar across the middle, or else a bar alone, which can by a suitable gear be lowered on to the top of the blast pipe.

A device to prevent too sharp a blast consists of a blast pipe top with an additional outlet for the steam (Fig. 15). Just below the orifice a number of holes are drilled horizontally to allow steam to pass into an outer annular chamber formed by a ring surrounding the pipe. This ring is free to lift vertically and has a seating on the top of the pipe. When the pressure in the chamber, and therefore in the blast pipe, becomes

excessive, the ring is lifted off its seat, allowing steam to escape, thus giving relief to the exhaust. The lift is controlled by suitable stops, and ribs are cast on the pipe to act as guides.

Spark plates prevent sparks from being ejected at the chimney, and

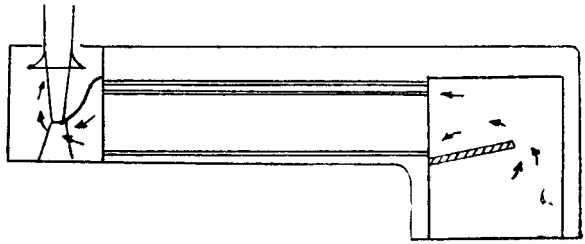

Fig. 16.

also have a large influence on the steaming of the engine by acting as baffle plates, and so deflecting the gases when they enter the smokebox. The sparks instead of being lifted straight up to the chimney are, to a large extent, deposited in the front of the box (Fig. 16).

The height of the bottom of the plate relative to the boiler centre is a matter for experiment, but is usually kept on a level with or just below the blast pipe top. The plate is carried forward a little beyond

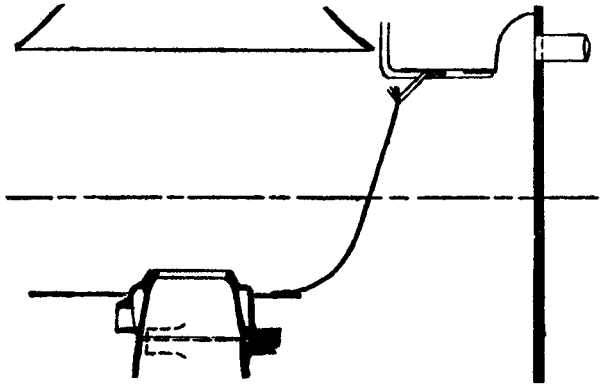

Fig. 17.

the blast pipe, this also being a matter for experiment, and depending to some extent on the length of the box (Fig. 17).

The advent of the superheater practically meant re-designing the smokebox. In order to protect the superheater tubes when steam is shut off ; the superheater header has to be enclosed in a box formed of

steel plates (Fig. 18). To bring the superheater into action when the regulator is opened, a damper is provided in this box which, when open, gives a passage for the gases through the superheater flues. The most suitable position is found to be underneath, and the damper is operated by a small cylinder carried outside the smokebox, to which steam is admitted when the regulator is opened, and as soon as steam is shut off the damper is closed either by means of balance weights or by a spring inside the cylinder.

When open to allow the gases to pass through the superheater, there is a tendency for the damper to act as a baffle to the tubes under it. As the lower tubes serve to generate steam while the upper ones superheat it, it is a matter for experiment to determine the proper opening for the

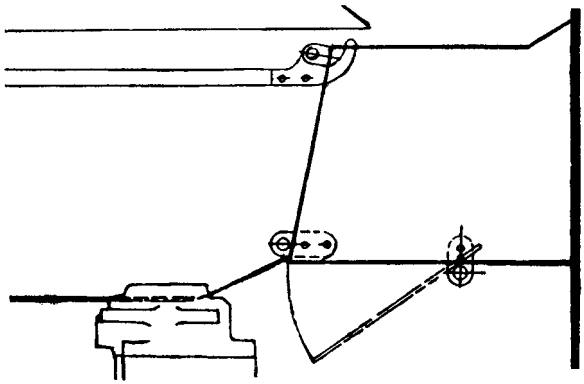

Fig. 18.

damper so that the right proportion of gases shall pass through the tubes and superheater flues.

Cases often arise of engines which are apparently fitted alike as regards blast pipe, chimney, spark plates, brick arch, etc, and whereas one will steam excellently, another for no, apparent reason will not steam at all.

A large amount of practical experience is required to deal successfully with the trouble, but even then cases do occur in which every device is tried without success, the result being that the engine has to go to the factory for a general repair, and the difficulty is overcome without the cause being traced.

Of course the trouble does not always rest with the smokebox, but in the majority of cases trouble in shortness of steam originates there.

It is thus evident that time is well spent in studying the design and principles of construction of the smokebox.