[No 84.]

G.W.R. Mechanics' Institution.

SWINDON ENGINEERING SOCIETY.

TRANSACTIONS, 1907-8

INTERMEDIATE MEETING.– Tuesday, Feb. 25th, 1908.
Chairman – Mr. A. H. Nash.

" LOCOMOTIVE SMOKEBOXES "

BY

H. ARKELL, (Member).

With Discussion.

THE smokebox is a necessary adjunct to a locomotive boiler. First, as a means of communication from the flue tubes to the chimney, and, secondly, to provide a sufficient vacuum to draw air through the ashpan, grate, and fire, and the products of combustion through the flue tubes, to the chimney. It is well known that this is done by discharging the exhaust steam from the cylinders through a " blast pipe," contracted at the point of discharge. This involves back pressure in the cylinders, and the problem of the designer is to get the required draught with minimum back pressure. Thus the efficiency of a smokebox may be expressed in terms of $\frac{\text{vacuum}}{\text{back pressure}}$ This is not all, however, as the draught should be evenly distributed over the tubes and should not cause sparks and cinders to be ejected from the chimney. All spark-arresting devices tend to lower the efficiency of the smokebox by obstructing the free flow of gases. On the other hand, some of them have a good effect by equalizing the draught.

Draught, or vacuum, is usually measured in inches of water, one inch of water = ·036 lbs. per square inch. A good running vacuum is three to four inches of water ; this is only about ·11 to ·14 Ibs. per square inch. The vacuum may be as high as 15 inches at base of chimney when working heavily at starting.

The draught required will, of course, be affected by conditions outside the smokebox. For instance, sufficient flue area, a proper diameter of flue tubes (about one to 90 in relation to their length), a sufficient grate area, and an efficient ashpan, all diminish the amount of vacuum required to maintain steam. A thick fire naturally offers more resistance to air passing through it than a thin one. Lengthening the brick arch in the firebox tends to prevent the lower tubes getting their share of gases.

The only really thorough investigation of smokebox action in recent years appears to be that conducted at Purdue University from 1894 onwards. The chief results of these very exhaustive trials will be found in Professor Goss's book, "Locomotive Performance," published last year. It should not be assumed, however, that these results can be applied without modification to English locomotives. Goss's experiments were carried out on typical American locomotives, having a large diaphragm in front of the tube plate, under which all the gases have to pass (Fig. 9). Professor Goss found that about 36 per cent. of the draught was absorbed by the diaphragm resistance, 33 per cent. by the tubes, and 30 per cent. by the fire, grate, and ashpan. If, therefore, the diaphragm be abolished or modified, the conditions in the smokebox must be considerably modified.

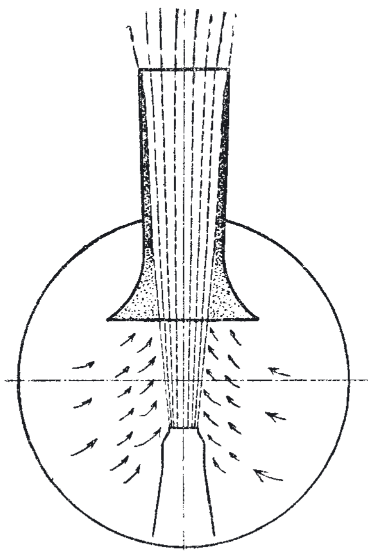

Fig. 1.

It used to be held that the action of the blast in the chimney was like that of a pump. Each puff of steam was supposed to act as a piston, and the ideal jet, it was said, should expand so as to fill the chimney at its base. The Purdue experiments did not confirm this idea.

It was found that the jet did not fill the chimney till nearly at the top (Fig. 1), and altered in size to suit the chimney. If a liner were put in the bottom of the chimney, the jet was reduced in diameter and did not fill the liner. There was a vacuum close to the sides of the chimney, gradually diminishing towards the top.

That the movement of the gases was towards the jet at every point and not directly towards the base of the chimney. The jet chiefly acts by induction on the surrounding gases, and also enfolds them to some extent, owing to a curious wavelike action in the jet. The induced action, however, is the most important. The gases surround the jet in a ring at the base of the chimney, and are gradually incorporated with it, though not completely. This was borne out by some quite independent experiments as to the quantity of sparks and ash ejected from the chimney. Fifty per cent. of the sparks, &c., were contained in a ring two inches wide round the circumference of the chimney. The first mentioned result is also explained, as the jet is bound to leave room between itself and the chimney for the gases it is carrying with it, and therefore cannot fill the chimney at the base.

That a steady blow of steam produced as high a vacuum as intermittent puffs, provided that the quantity of steam discharged per unit of time was the same. If one thinks of the effect produced by a small blower this seems quite reasonable.

Draught is nearly proportional to weight of steam discharged per unit of time, and is not much affected by speed or cut-off, except of course as these affect the said rate of discharge. The Author did not think that the two last mentioned results would hold good with smokeboxes of small capacity.

Smokeboxes used to be made as small as possible. The diameter was always somewhere near that of the boiler barrel, but the length was kept short. It is probable that American smokeboxes were originally lengthened only to make room for the netting and other spark-arresting devices with which they are fitted.

In a short smokebox the chimney must be close to the tube plate, and the gases have a very sharp turn to make on their way to the chimney. When the engine is working heavily the draught is extremely fluctuating, rising and falling with each puff of steam. Each puff makes a high vacuum in a small box, causing a violent rush of gases through the tubes, filling the smokebox and destroying the vacuum. Then there is a sort of back rush through the tubes. The effect on the fire is very bad. At high speeds, when the blast is lighter and more frequent, the small smokebox will give better results than at low speeds.

It has been contended by the advocates of small smokeboxes that they can use a larger blast-pipe nozzle, as there is less to exhaust from a small box. But the quantity of gas to be exhausted depends on the rate of combustion, so that there is the same quantity to be discharged from the chimney in a given time whether the smokebox is large or small.

A large smokebox acts as a vacuum reservoir, and gives a much more even draught.

The chimney can be placed well forward from the tube plate, thus equalizing the draught through the tubes. It has been objected that eddy currents are formed in the front portion of a long box, but we shall see later, that this is not so if properly arranged baffle plates are used. Eddy currents are much more probably formed at the top of the box, and at the bottom, where there is a " well " over the cylinders. Improvement in steaming has resulted from filling up the space over the cylinders with fireclay, in smokeboxes of ordinary English pattern (Figs. 2, 3, 12). Benefit has been found to result from lining up the top of the smokebox with a plate, but this makes access to the pipes, &c., inconvenient. It appears then to be a step in the right direction to reduce the diameter of the smokebox to about that of the boiler barrel, and to abolish the " well " by making the smokebox circular. This is also a convenient arrangement from a constructional point of view.

Perhaps the grate area is the most suitable dimension with which to tabulate the smokebox capacity, and a table is given herewith.

Boiler.	Capacity of Smokebox. Cubic feet.	Grate Area. Square feet.	$\frac{\text{Capacity.}}{\text{Grate Area.}}$
Great Western, No. 6 ...	185	41·79	4·42
,, 1 ...	117	27·07	4·32
,, 4 ...	101	20·56	4·92
,, 2 ...	82·5	20·35	4·08
,, Std. Goods ...	48	17·33	2·78
Great Central, 4-4-2 ...	125	26·00	4·88
Lancashire & Yorkshire, 4-4-2	117	26·05	4·49

It will be seen that modern " extended " smokeboxes have a capacity in cubic feet of about four to five times the grate area in square feet.

Chimneys.—In general, it is true that increased height of chimney gives increased draught, within any limits practicable on a locomotive.

Goss found that the loss of vacuum from reducing the height of the chimney from 56 inches to 26 inches averaged 1·6 inches of water. Though this loss may be lessened by suitable arrangements, it cannot be entirely prevented. It is not possible to use long chimneys on large modern locomotives, owing to the restricted loading gauge. Short chimneys must be of smaller diameter than long ones. The chimney should increase in size as the blast pipe is lowered, owing to the divergence of the exhaust jet, although as we have seen, the jet will accommodate itself to the chimney to a great extent. Petticoat pipes enable a smaller chimney to be used, as they keep the jet small. Goss found that tapered chimneys gave better results than straight ; the Von Borries Halske tests, in Germany, about 1895, arrived at the same conclusion. Chimneys increasing in diameter to the top are meant ; Great Western chimneys used to be tapered the other way. The standard chimney still in use on goods and small passenger engines is 14 inches diameter at the base and 13 inches at the top. The diameter of a chimney may be considerably varied without much affecting the engine. Goss found that a variation of two inches to even four inches in diameter made little difference. The standard Great Western Railway cast iron chimney is used with No. 4 boilers and 18-inch × 30-inch cylinders, and with No. 5 boilers and 16½-inch × 24-inch cylinders ; and one American " master-mechanic " has stated that they used the same chimney for all sizes of engines from 16-inch × 22-inch to 25-inch × 26-inch (Mr. Mitchell). Probably the reason of this wide range is that the small chimney contracts the jet (as we have seen), making it more dense and powerful, so that it takes the gases out with it at a greater velocity ; thus the chimney is a sort of self-compensating arrangement. Still, an effort should be made to give the chimney a proportionate diameter to the work to be done.

Blast Pipes—The American master-mechanics considered the form of nozzle shown in Fig. 1 to be the best, as giving the densest and most powerful jet. The top of the nozzle is parallel for about an inch downwards ; a diverging jet used to be sought after, but now the reverse is sought. The height of the blast pipe is a most important matter. Generally speaking, it should vary with the height and diameter of the chimney, but the best height for any class of engine can only be found by experiment. One instance of the importance of this point may be given from Goss.

Position of Nozzle.	Back Pressure. lbs. per sq. in.	Vacuum. ins. water.	Co-effic.
20 inches above boiler C.L.	2·35	3·2	·049
5 inches below ,,	2·27	5·0	·079

(Chimney, taper 11¾ inches to 18¾ inches × 56 inches high ; speed, 40 miles per hour; revolutions per minute, 194 ; cut off, 27%).

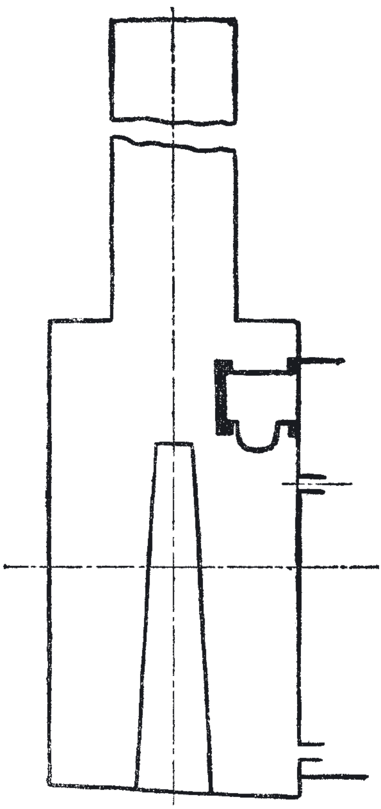

Fig. 2.

Early locomotives had the end of the exhaust pipe simply turned up the chimney. It was soon found that better results were obtained by placing the blast pipe below the chimney. Fig. 2 shows a Great Western smokebox of 1870, and it is typical of a practice which lasted 50 or 60 years, and still survives. This arrangement gives an unequally distributed draught, very strong through the upper middle tubes and much less through the outer and lower ones. Mr. R. Weatherburn, a few years ago, found that copper melted in the top middle tubes (at firebox end) showing a temperature of about 1950° Fahr., while lead would not melt in some of the outer tubes, which did not reach 612° Fahr. The lower tubes require, if anything, a stronger draught in order to get their share of gases, as the latter have to pass up over the brick arch in the firebox, and tend then to pass through the upper tubes.

When boilers began to be pitched higher, chimneys were necessarily shortened at the top, and were lengthened again by extending them down into the smokebox (Fig 3). The blast pipe nozzle was then lowered to about the level of the top row of tubes. The uneven draught difficulty, however, probably became worse than before. With the old arrangement the distance of the nozzle above the tubes equalized the draught to some extent ; with the arrangement shown in Fig. 3 the jet was quite close to the top middle tubes, and a very fierce draught would be caused through them to the jet, to the neglect of the other tubes. This had a very bad effect on the fire. No doubt competent firemen neutralized this by skilful firing, having found by experience the spots where the fire required to be thickest.

Adams' Vortex Blast Pipe (Fig. 4).—This was an attempt to equalize the draught between the upper and

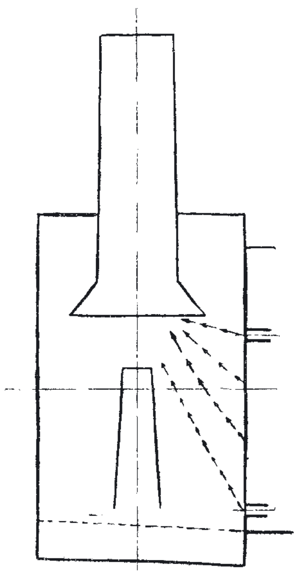

Fig. 3.

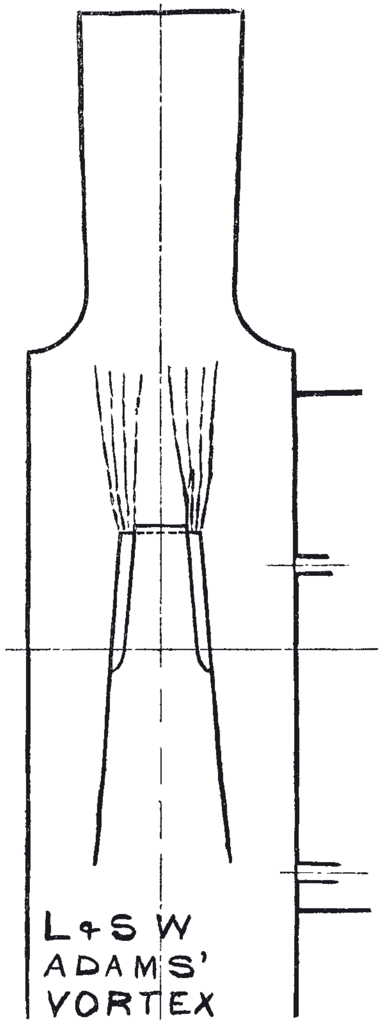

Fig. 4.

lower tubes. The blast pipe was annular, the exhaust steam being discharged through the outer ring, and the central passage ran down to an opening opposite the lower tubes. Great results were claimed for it on the London and South Western during Mr. Adams' regime, but it is not now in use. Taking the theory that the gases flow towards the jet, the lower tubes would not benefit much ; there might be some suction through the central opening, but in any case, the outer tubes would not benefit at all. The annular form of jet is not a good one, not being so dense as the solid jet. Also, blast pipes get encrusted inside, and an annular jet offers a larger rough surface to the steam, increasing back pressure.

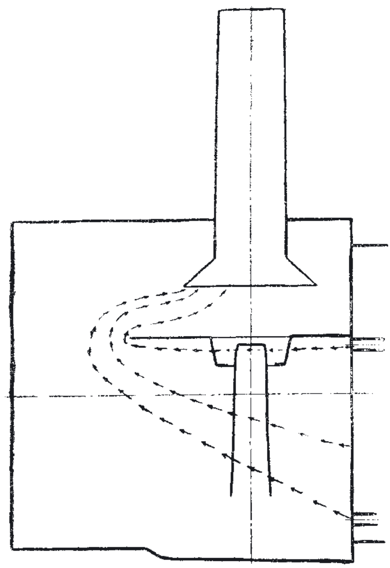

FIG. 5.

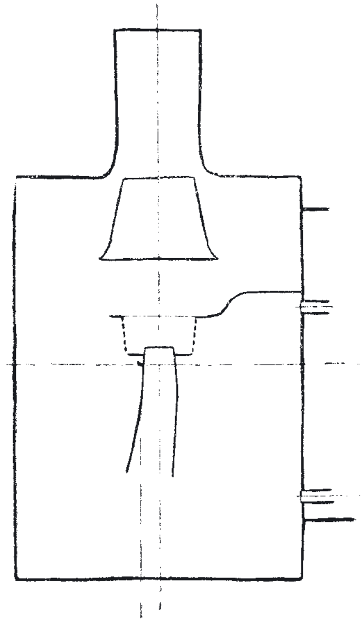

FIG. 6.

Fig. 5 shows the smokebox introduced in 1895 on the Great Western "Duke of Cornwall" engines. This was quite a new departure for this country, and proved an immediate success for heavy work. It will be seen that the smokebox is of large capacity, and that a horizontal diaphragm, or baffle plate, is used. This is placed just above the tubes, and extends forward from the tube plate for about two-thirds of the length of the smokebox. Thus, instead of the gases being drawn straight from the nearest tubes to the jet, they have to pass along under the diaphragm and up round the front. This gives a fairly even draught over the tube plate. Most of the cinders will also be dropped at the front of the smokebox, where there is plenty of room for them.

Many of the smokeboxes of the pattern shown in Fig. 3 have been greatly improved by being extended by about nine inches to twelve inches, and having a horizontal diaphragm fitted, thus making them similar in principle to Fig. 5, though of smaller capacity. With baffle plates of this design it is not necessary for the chimney to be placed further forward from the tube plate than in old small smokeboxes.

A very similar smokebox is used on the Great Central Railway (Fig. 6). The blast nozzle is somewhat lower and is placed in a well in the baffle plate.

In 1899 the large, high-pitched No. 2 Belpaire boiler was introduced on the Great Western Railway. A very short chimney was necessary for the 6 feet 8 inch wheel engines, having the boiler centre 8 feet 3 inches from rail. A taper cast iron chimney was adopted, only 13 inches diameter at neck, and a suspended petticoat pipe was used. The blast nozzle was 11 inches below centre of boiler, much lower than it had been placed before on this line. The smokebox was long and of reduced diameter. After some alteration in the position of the petticoat pipe this smokebox proved very successful, and was standard until recently on all engines with Nos. 2 and 4 boilers (Fig. 7).

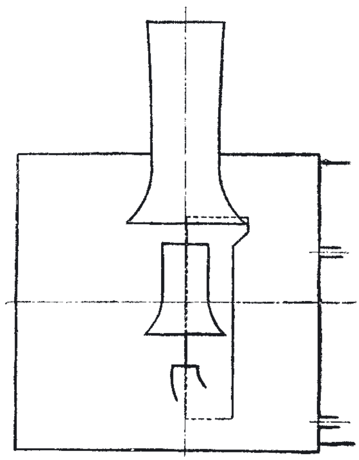

Fig. 7.

The petticoat pipe keeps the jet contracted, increasing its efficiency and enabling a small chimney to be used with a low blast pipe. Assuming that the gases flow towards the jet, they will be drawn towards it at the gaps above and below the petticoat pipe, thus equalizing the draught vertically over the tubes. This, however, does not help the outer tubes, and so a vertical semi-circular baffle plate is used, placed behind the blast pipe and concentric with it. It is suspended on a ring on the chimney bell, and can be turned round to afford access to the tubes, one side at a time. The gases have to pass round the sides of the baffle plate in order to reach the chimney. The draught is thus equalized, though it would appear that in this case the middle tubes would hardly get their share. The baffle plate is carried down to four inches above the bottom of the smokebox, so that there cannot be much draught underneath it. Cinders will be carried round the sides and to a great extent deposited (Fig. 8).

One disadvantage of a petticoat pipe is that it decreases the length of jet in contact with the gases, and this would more or less counteract the increased induction due to the greater velocity of the jet.

Professor Goss, in his latest experiments, reports unfavourably on the use of petticoat pipes. But the smokebox in which they were tried had a large diaphragm, as shown in Fig. 9, extending right across the tube plate and down nearly to the bottom of the smokebox. Thus the gases cannot pass round the sides, as in the Great Western arrangement, but must all pass under the diaphragm. The top exposed portion of the jet is a long way from the tubes. Therefore, in this case it would seem reasonable to bring the upper exposed portion of the jet lower down, and to do this by abolishing the petticoat pipe and lengthening the chimney bell downwards.

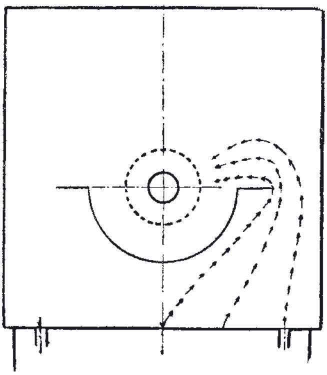

FIG. 8.

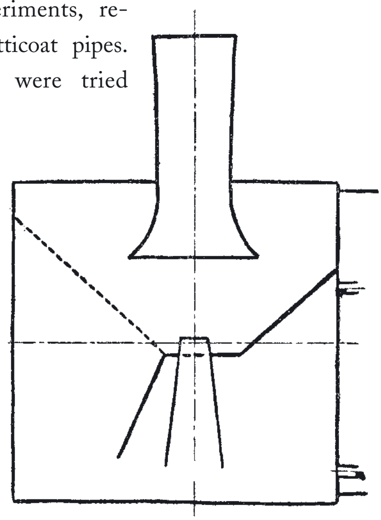

FIG. 9.

The present Great Western standard smokebox is shown in Fig. 10. Instead of using a petticoat pipe the chimney is enlarged and extended well down into the smokebox. It has a large bell-mouth base. This was found by Professor Goss to give practically as good results as a plate in the top of the smokebox, without the inconvenience resulting from the use of the latter. The chimney is tapered outwards and the blast pipe is low. Experiments are now in progress to determine the best height of nozzle for various classes of engines. The vertical semi-circular baffle plate is used, and its action on the gases is much the same as in the No. 2 smokebox with the petticoat pipe. It has, however, been cut shorter, so that there is an almost direct path from the lower tubes to the jet. This would seem undesirable ; but, perhaps it has been found necessary to give

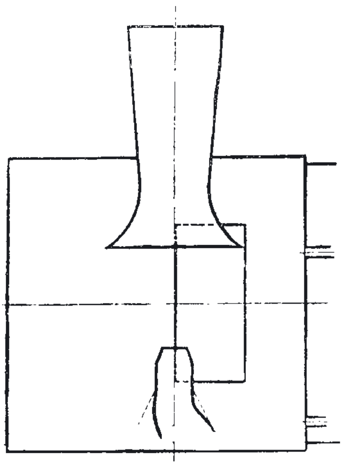

Fig. 10.

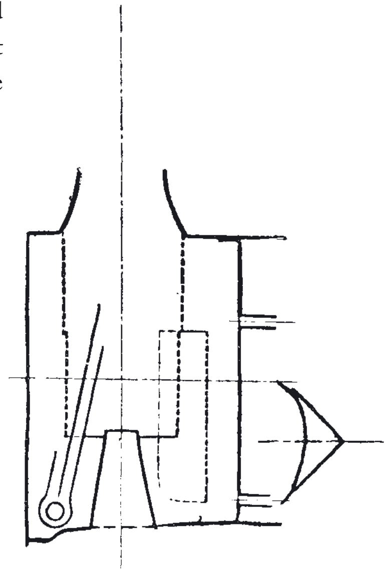

Fig. 11.

the lower tubes more draught, owing to a long brick arch for instance, or some other reason.

On account of the different form of diaphragm or baffle plate used, the path of the gases in this smokebox is quite different from that in Professor Goss's recommended design, though the proportions of the various parts are very similar. There is a limit to the lowness of the blast pipe nozzle, as cinders accumulate in the smokebox, and are liable to be drawn into the blast pipe when the engine is running with steam shut off. This has happened with serious results.

A smokebox with spark arrester (Fig. 11) was fitted to a small main line engine on the Midland Ry., the author has not been able to obtain any information as to its working, but the smokebox appears very much choked up, and one would think that the draught must be reduced. The arrangement of netting or perforated plate can be seen on the diagram. An " ash ejector " is fitted. There is an inclined pipe divided by a midfeather, and having a lower chamber with holes. The upper opening is brought to the edge of the exhaust jet ; a vacuum is created in the pipe, ashes are sucked in at holes in the lower chamber and carried up into the jet and up the chimney ; they are all supposed to be dead before this takes place. A simpler device for the same purpose is used on the London and North Western express engines, " Precursor " class. A perforated pipe runs along the bottom of the smokebox at the front end. When steam is turned into this pipe the accumulated cinders are blown up, caught by the blast, and ejected from the chimney. The author inquired how it answered, and was told to ride in any main line train and hear the cinders dropping on the carriage roofs. There is no baffle plate of any kind ; the smokebox is of fair capacity ; the chimney is extended down into the smokebox and the blast nozzle is about on the centre line of the boiler. Unless a diaphragm or baffle plate is used, it is difficult to see the advantage of extending the smokebox to the front of the chimney. The gases pass directly from the tubes to the jet, as in a small box. There is, of course, the advantage gained from a large cubic capacity ; but if the baffle plates are not used it would seem that the chimney should be placed well forward in a long smokebox.

The Lancashire and Yorkshire smokebox (Fig. 12) is a good example of this, although it is probable that other considerations determined the unusual arrangement. The engine is of the inside cylinder 4-4-2 type and the cylinders drive on to the leading coupled axle ; therefore they have to be placed well forward to secure sufficient length for the connecting rods. The blast pipe and chimney were placed vertically over the cylinders, and the smokebox lengthened backwards into the boiler barrel. The distance of the chimney from the tube plate is 3 feet 10 inches ; this would certainly have the effect of partially equalizing the draught over the tubes, since if the chimney were at an infinite distance from the tube plate, the draught would be completely equalized.

North Eastern smokebox (Fig. 13) does not call for much comment. It is of small capacity for a large 20 inch × 28 inch 4-4-2 engine, and there appears to be no attempt at equalizing the draught. The base of the extended chimney is of a very bad shape.

To return to spark arresters : Both on the Continent and in America it is usually considered necessary to use some sort of spark arrester, but their use is by no means general in this country, though extending. The object of a spark arrester should be not only to catch the sparks and cinders in the smokebox, but to prevent their getting there, as far as possible. Spark arresters either consist of netting or mesh acting as a strainer ; or baffle plates; or both in combination. The simplest form

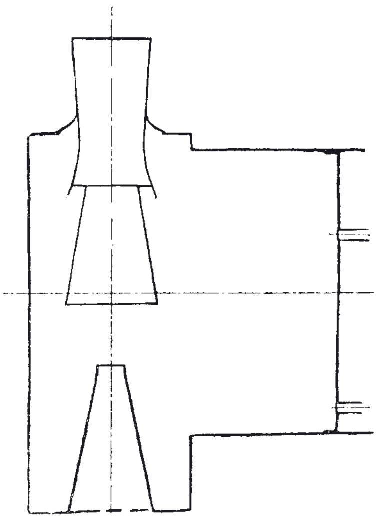

Fig. 12.

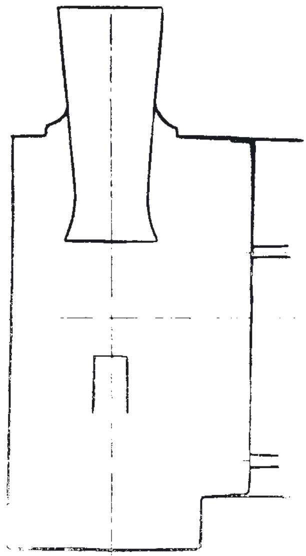

Fig. 13.

of netting extends horizontally across the smokebox just above the tubes, the blast pipe projecting through it ; another form is cone-shaped and encloses the jet, extending from the blast nozzle to the base of the chimney ; another variation is shown in Fig. 11. No doubt netting stops the larger cinders from being thrown out of the chimney, but if the mesh is fine enough to effectively stop the sparks, it will seriously obstruct the draught : also, netting does not in any way equalize the draught, and thus prevent the drawing of sparks into the smokebox. Now baffle plates, properly situated, equalize the draught through all the tubes very fairly ; cinders will of course be drawn through the tubes to some extent, but they will be mostly deposited in the smokebox, owing to the path the gases have to take, and only the finer ashes get carried up the chimney.

It is said by some that the use of baffle plates requires a fiercer blast owing to the circuitous path the gases have to take in the smokebox, but this is more than compensated for by the even draught through all the tubes, taking advantage of the whole flue area, and promoting even combustion on the grate instead of drawing the gases at a high velocity through only a part of the tubes and pulling the fire into holes. As previously mentioned, a good fireman will get to know the weak points of his firebox, and by keeping a thick fire at the critical spots will manage to get along all right as a rule ; but if the fire becomes thin at those spots when working heavily, air rushes through the grate and sparks are thrown anyhow. It is no doubt owing to good firing, good coal, and a moderate rate of combustion, that small, plain smokeboxes have survived so long in this country. In American practice netting is used in addition to a diaphragm or baffle plate ; the netting usually extends upwards from the front of the diaphragm to above the smokebox door (Fig. 9) or horizontally across the box above the tubes.

Even when spark arresting devices are used a considerable quantity of sparks will be thrown out of the chimney. Goss's earlier experiments with a locomotive fitted with a diaphragm and netting included an investigation of the spark losses. An extract may be given :

	Smokebox vacuum ins. of water.	Coal per sq. ft. per hour. lbs.	Sparks ejected from chimney per hour. lbs.	Sparks caught in smokebox per hour. lbs.	Ratio of sparks to coal burnt.
(1)	1·9	45	21·9	12·3	·043
(2)	3·0	89	45·0	63·4	·070
(3)	5·0	121	215·5	78·0	·138

Except in the case of test (3) the sparks which passed up the chimney were probably chiefly fine ash, and would not do much harm. Test (3) was run in 80 per cent cut off at 15 miles per hour, and the sparks were cinders of good size. These results do not say much for the efficiency of netting.

The Author had intended to give a table of efficiency, that is to say, a comparison of vacuum to back pressure. But results obtainable are so few and so utterly conflicting that he has been unable to do so, and merely gives a few incomplete figures.

From trials of Adams' outside cylinder 4-4-0 engine with vortex blast pipe (Fig. 4).

Trial		Back Pressure lbs. per sq. inch. (Max).	Vacuum Base of Chimney ins. water		Vacuum Top of Blast Pipe. ins. water	Vacuum Middle Tubes.
1 (a)	at max. I.H.P.	10·0	max.	8·5	7·5	6·2
(b)	at max. speed	5·3	mean	4·9	4·3	2·8
2 (a)	...	6·6	max.	11·0	7·1	5·8
(b)	...	5·7	mean	6·4	4·1	3·3
3 (a)	...	15·6	max.	14·0	11·1	8·0
(b)	...	6·1	mean	6·5	4·2	3·8
4 (a)	...	13·9	max.	15·0	12·8	9·0
(b)	...	5·9	mean	7·3	6·2	4·8
5 (a)	...	7·6	max.	7·0	6·8	5·4
(b)	...	7·7	mean	3·8	4·9	3·8

Area of annular exhaust 13·9 square inch = $4\frac{7}{16}$ ins. diam. circle.

Goss's latest experimental smokebox finally recommended gave results :

Back Pressure.	Vacuum.	Coeffic.
3·5 lbs. square inch	4·98 ins. water	·05

But in some of his older experiments he obtained coefficients up to ·082 :

2·1 lbs. square inch.	4·8 ins. water.	·082.

The taller chimney, 56 inch, as against 29 inch, may have had something to do with it, but the figures cannot be considered satisfactory for the modern engine. Boiler pressure of the earlier engine was 130 lbs. square inch and of the later one about 200 lbs. square inch.

Engine 3003, 4-2-2, Paddington to Swindon.

Smokebox Vacuum.	Cut Off.	Blast Sharpener.
$2\frac{1}{4}$in water	17 per cent.	Off.
3	23 „	Off.
$4\frac{5}{8}$	26 „	On.

Macallan's Variable Blast Pipe. Great Eastern Railway.

		Vacuum with Sharpener On.	Vacuum with Sharpener Off.
Bottom Middle Tube	...	2·8	2·3
Top „ „	...	2·6	2·1
Outer Middle	...	1·6	1·3

Plain blast pipe level with top row of tubes. No petticoat or baffles. Figures for bottom tubes do not agree with general experience.

Goss's table of vacuum required to burn so many pounds of coal per square foot of grate per hour.

Vacuum. ins. water.	Coal per square foot of Grate per hour, lbs.
2·0	50
2·7	70
3·3	90
4·1	110
4·8	130
5·5	150

The Author has endeavoured to set forth a few leading principles of smokebox design, although it is not a subject upon which one should dogmatize, as we know very little about it ; however, we have now a working hypothesis, which gives better results than the old haphazard practice, though it may possibly be only partially true. Varying conditions of work required, quality and kind of coal, method of firing, and design of other parts of the engine and boiler must always make comparisons difficult.

DISCUSSION.

Mr. A. H. Nash, in opening the discussion, congratulated the Author on his interesting paper. He (Mr. Nash) thought it a great pity the Goss experiments had not been repeated in this country. In the old method of designing the blast pipe was set at such an angle that the jet struck the chimney about one-third from the bottom. He should like to know the angle and shape of the jet. He thought the shape of the smokebox should be something after that of the path of the gases. What were the Author's views ? He believed the L. & N.W.Ry. tried a smoke box having a diaphragm fitted across the box. One cylinder exhausted into the upper portion and the other into the lower, each having a separate chimney and so obtaining an equal flow of gases through top and bottom tubes. With regard to the position of the chimney of a locomotive, he thought it a good idea to get it well forward.

Mr. C. T. Cuss asked what device was used for measuring the vacuum. With reference to blower-pipes : what were the Author's views on the value of the blower being turned into the neck of the chimney? Referring to the exhaust jet, Mr. Cuss asked why the nozzle should not be flattened so as to produce a flat spreading jet, and thus equalize draught from side tubes. He also spoke on the subject of leakage of smokeboxes and burning of doors.

Mr. R. G. Hannington, while asking several questions relating to blast pipes, mentioned that some of the French railways used a rifled blast pipe. With regard to smokeboxes, was there any advantage in having small fastenings at various points round the door, as arranged on the French engines; was it a good feature?

Mr. W. A. Stanier, referring to blast sharpeners, said the ring often gave trouble. He considered the "Jemmie" to be the better arrangement. With regard to ashes getting into low blast pipes, he said this had been overcome by raising the pipes. In long runs it had been found necessary on some occasions to clean out the front end. With a run from London to Plymouth, it had been found on arrival that there were ashes to the depth of about seven inches.

The Author, replying to the various questions, said there was no particular angle of jet. The jet accommodated itself to the chimney to a large extent. If liners were placed in the bottom of the chimney the jet would still clear them. With regard to the proposed tapering of the smokebox to the path of the gases: Some time ago a coned smokebox was suggested in "The Engineer," and warm discussion followed. The arrangement would not leave sufficient space for cinders, and they would slide back into the lower tubes. Another serious objection was the inability to obtain access to the tubes. With regard to the L. & N.W. double chimney, the Author said he believed only a few engines were fitted, and remained so only a short time.

In answer to Mr. Cuss, the Author made a black-board sketch of the device for measuring the vacuum, which mainly consisted of a graduated sliding tube, which was pushed through glands in the side of the smokebox, and connected to a **U** tube on the outside for water pressure. To ascertain the shape of the steam jet, the tubes were bent at right angles and brought to a fine point. The arrangement was simple, and by it pressure as well as vacuum were recorded, and the outline of the jet was ascertained.

With regard to the position of blower-pipes, the Author said they did very well round the blast pipes when the nozzles were high, but with low nozzles the distance to chimney was too great for a feeble jet to travel.

The objections to introducing a flat jet are the inability to spread it sufficient to appreciably benefit the outer tubes, and the weakening of the jet. The increased surface for induction would not compensate for decreased velocity. The induction effect probably varied as the velocity squared, but only directly as the surface.

Smokebox leakage and the burning and warping of doors were important points. The arrangement of fastenings on the French engines the Author considered good.