The valves are designed so as to give as little clearance as possible, thereby giving a great efficiency in output, and they are so arranged as to be readily withdrawn from the head for examination purposes when required.

The speed of the pump is 250 r.p.m., and when compressing to 90 lbs. per square inch it will deal with about 38 cub. ft. of free air per minute. It is automatically controlled by means of an electric switch and governor, by which the motor is cut out of circuit when the pressure in the main reservoir has reached the maximum to which the governor is set, and is cut into circuit again when the pressure has dropped to the minimum to which the governor is also set.

Superheaters in Locomotives on the Belgian State Railways.*

By Mons. J. B. Flamme, Inspector-Général de l'Administration des Chemins de Fer de l'Etat Belge, Brussels.

The Belgian State Railway has recently put in service a series of simple expansion locomotives, the boilers of which carry a pressure of 14 atm. (205·8 lbs. per sq. in.), with an inside diameter of 1·600 m. (5ft. 3 ins.), while that of the cylinder is 520mm. (20½in.). This class of engine gives the maximum power obtainable by the simple expansion of steam. In fact every new enlargement of the cylinders would demand larger dimensions for the crank-axle and moving parts; on the other hand, the necessity for clearing the loading-gauge limits the diameter of the boiler; in short, with simple expansion it would be difficult to utilise steam with a pressure exceeding 14 atm.

Under these conditions and in view of further increasing the power of the engines it becomes necessary to resort to some other system for increasing the useful work of the steam without enlarging the existing boilers.

The two solutions under consideration are compound working and superheating of the steam. The first of these does not strictly come within the limits of this paper.

Arrangements for producing superheated steam and the results obtained with a system that has been in service for more than a year will now be considered.

Schmidt Superheater for Simple Expansion Locomotives.

For some time the Locomotive Department had their attention drawn to the favourable results obtained by using superheated steam in industrial stationary engines. By superheating the theoretical cycle is improved, and the pressure is maintained The volume of steam is augmented proportionately to the rise of temperature, diminishing, however, its density. In other words, when the degree of superheat is sufficient to prevent the loss due to condensation in the cylinders, then the surplus heat contained in superheated steam is sufficient to reheat the walls of the cylinders, maintaining the temperature necessary to get rid of the condensation and the loss of work during expansion. These trials have brought to light a valuable property of superheated steam. It was recognised as a bad conductor of heat, contrary to that which obtains when steam is in the saturated state.

These numerous advantages, tested by many trials undertaken by most competent engineers, are specially valuable to the locomotive engine. The employment of a practical superheater augments the power of the boiler, and the utilisation of superheated steam is most economical. This is well observed in hauling heavy goods trains on sections of the line having heavy gradients. For it is then indispensable to reduce to the minimum the consumption of water and steam. For the suburban trains having frequent stoppages superheat is again highly recommended, because it reduces the condensation necessitated by the frequent stops. High speed is also favourable to the employment of higher superheated steam, the great fluidity of which, as well as its dryness, permit running with early cut-offs, which helps the boiler just at the time when it is most hard pressed.

On the other hand, the passage of saturated steam through the pipes (and steam ports) is more difficult, and entails inevitably an increase of condensation. Having in mind these various theoretical and practical considerations the administration of the Belgian State recognised the great utility of pushing on their investigations in this direction.

It was in 1900 that the administration of the State Railways opened negotiations with M. Schmidt, the German expert, who at that period had already introduced some locomotives with steam superheaters formed principally of a series of rings placed in the smoke-box.

This last plan, described in most of the technical newspapers, and applied to a Prussian State locomotive shown in Paris in 1900, adapted itself without difficulties to outside cylinder engines.

It is not quite the same for inside cylinder engines which, as in England, are generally used in Belgium. In this case it becomes impossible to clear from the bottom of the smoke-box the cinders brought by the large flame-tube placed at the base of the barrel.

On the other hand, a superheater, established in the barrel of the boiler and described later (fig. 5) offers some real advantages. It is lighter, less cumbersome, easy to clean and maintain, and its introduction does not necessitate any important modifications in the smoke-box. Consequently it was this kind of apparatus that the Locomotive Department adopted in a new type of powerful locomotive then being built in the Cockerill Works at Seraing.

At the same time another important question presented itself. Was it absolutely necessary to superheat the steam to a temperature reaching 300° to 350° C. (572° to 662° F.)? It is evident that the more the steam is superheated the more necessary it becomes to give attention to the oiling of the piston-valves and cylinders and to the construction of the stuffing-box. With a view to getting a clear idea of the actual amount of superheat some trials were made with a superheater of small surface installed in the barrel of one of the locomotives, type 35, which will be described later. After several months of experiments it has been recognised that the utilisation of steam slightly superheated does not offer any appreciable economy of fuel or increase of power.

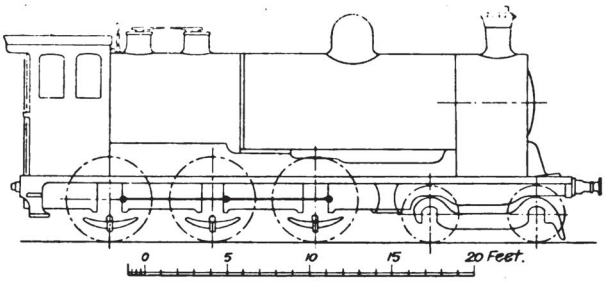

Fig. 1.—Six Wheels Coupled Locomotive; Belgian State Railway,

On the other hand, with the Schmidt apparatus placed on a locomotive, type 35, figs. 1 to 4, and provided with steam with a temperature varying between 300° and 350° C. (572° to 662° F.), some favourable results have been obtained.

The locomotives compared, one using saturated steam and the other superheated steam, are both of type 35, with six coupled wheels of 1·600m. (5ft. 3ins.) with bogie in front. The boiler has a round-topped fire-box, the roof of the furnace being connected to the arch by vertical stays. The fire-box, of a medium depth, burns coal with briquettes varying in quantity with the weight of the trains. The inside cylinders are made with piston slide-valves placed above, steam being admitted in the middle of the valve. This arrangement, with the Stephenson valve-gear, involves the employment of a rocking-shaft, which reverses the position of the valves compared with those having the exhaust port in the middle of the piston-valves.

The six coupled wheels and the bogie are fitted with compressed-air brakes. The engine is illustrated in figs. 1 to 4.

*Read before the Institution of Mechanical Engineers at Liége, June, 1905.

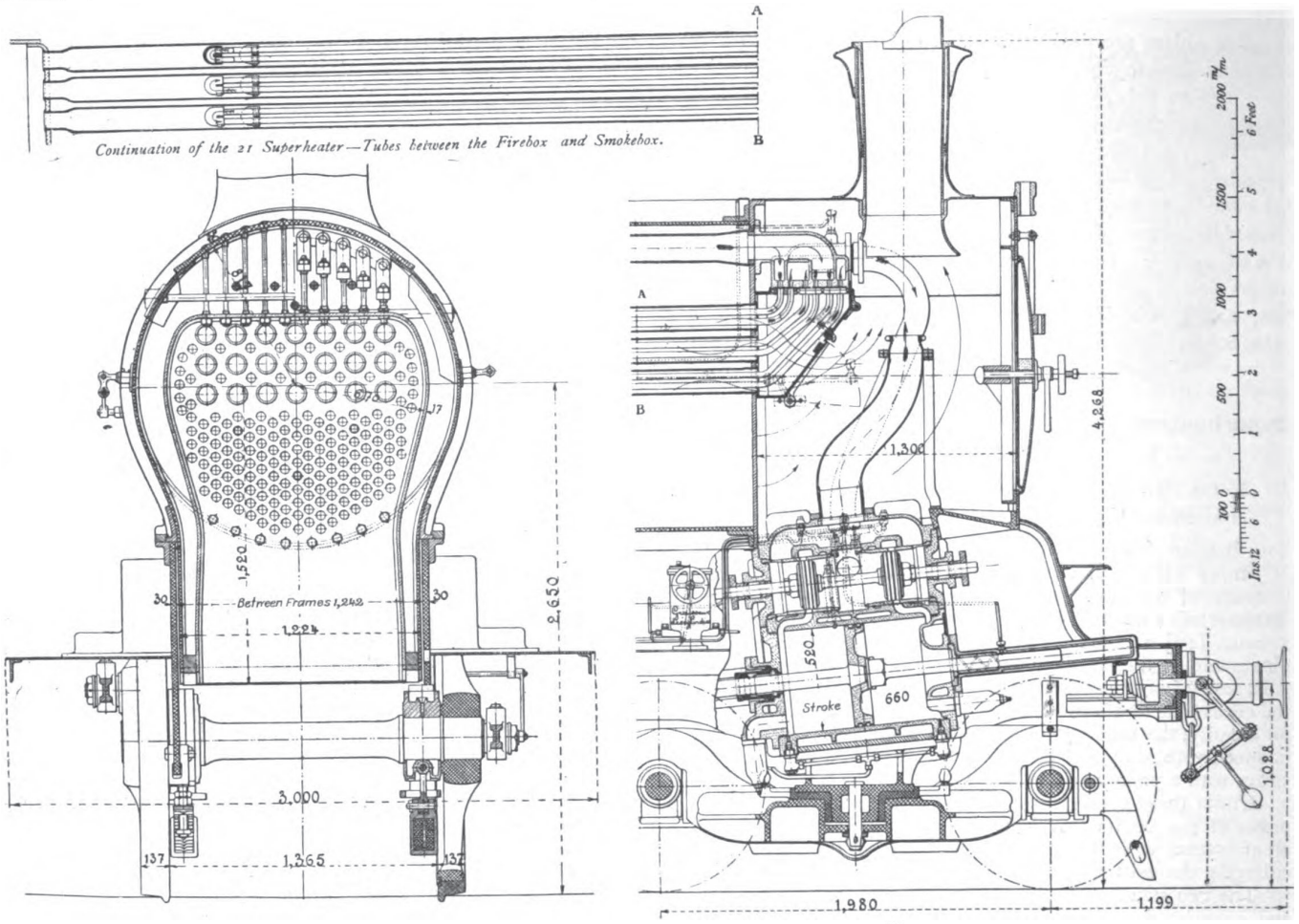

Fig. 4. Fig. 2.

Six Wheels Coupled Locomotive, fitted with Schmidt Superheater; Belgian State Railway.

The principal dimensions are given in the following table:—

Cylinders:—	
Diameter	520mm. (20½ins.)
Stroke	660mm. (26ins.)
Working Pressure	14atm. (205·8lbs. per sq. ft.)
Diameter of driving wheels ...	1·600m. (5ft. 3ins.)
Height of centre of boiler above rail	2·650m. (8ft. $8\frac{1}{16}$ins.)
Tubes:—	
Length	4·130m. (13ft. 6½ins.)
Exterior Diameter	50mm. ($1\frac{15}{16}$ins.)
Number...	271
Heating surface:—	
Tubes, internal	158·25 m². (1,703 sq. ft.)
Fire-box	14·90 m². (160 sq. ft.)
Total	173·15 m². (1,863 sq. ft.)
Grate surface	2·84 m². (30½ sq. ft.)
Weight in running order:—	
1st axle...	9,740 K. (9.5 tons).
2nd ,, ...	9,740 K. (9·5 tons).
3rd ,, ...	18,215 K. (17·9 tons).
4th ,, ...	17,850 K. (17·5 tons).
5th ,, ...	17,500 K. (17·5 tons).
Total weight	72,965 K. (71·8 tons).
Adhesion weight	53,565 K. (52·7 tons).
Tractive effort $p\,d^2\,l/D=$	16,128 K. (15·8 tons).

The engine provided with the Schmidt superheater has less heating surface than the above, owing to the substitution of 21 tubes of 118 mm. ($4\frac{5}{16}$ ins.) diameter for 103 tubes and 50 mm. ($1\frac{15}{16}$in.). For this locomotive the internal heating surface in the tubes is 98·10 m.² (1,056 sq. ft.) and the total heating surface is 130·056 m.² (1.400 sq. ft.).

The exterior superheating surface is equal to 27·15 m.²

The superheater proper is illustrated in figs. 2-4, and consists essentially of two parts.

(1) A series of iron tubes of 118 mm. ($4\frac{5}{16}$ins.) external diameter, occupying the upper part of the nest of tubes and offering like them a passage for flame and hot gases.

(2) Some U shaped tubes grouped in pairs among the flame tubes and used for the circulation of the superheated steam.

A steam collector in several divisions is placed on the top of the smoke-box. Some supplementary parts complete the system.

There must also be a diaphragm to close the flame tubes when steam does not circulate in the superheating tubes. This diaphragm is handled by the aid of a lever near the engine driver.

A mercury thermometer shows the temperature of the superheated steam at the entrance of the steam-pipe. The degree of superheat is read on a graduated quadrant placed in the cab.

The large flame-tubes, which are of solid drawn iron, are screwed into the fire-box tube-plate and expanded in the smoke-box tube-plate.

The superheating tubes, also of solid drawn iron, are protected against the action of the flame at the fire end by cast-steel caps.

In the smoke-box these tubes are expanded into flanged bushes fixed by bolts. The tightness is assured by means of asbestos joints.

Copper, bronze and brass are usually excluded from all parts that come in contact with the superheated steam. For this reason the steam pipes are of iron, and the joints between these pipes and the cylinders are formed with cast-iron flanges.

The metallic packings of the piston-rods and valve-spindles are composed of cast rings and white metal, the contact of which on the rod is obtained by a spring permitting small side movements of the rod.

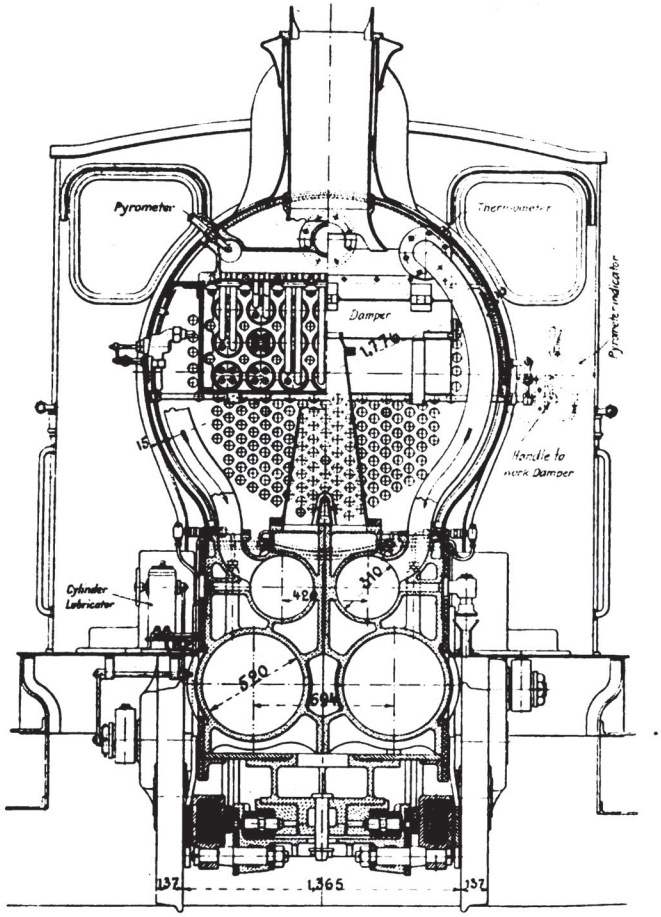

Fig. 3.—Six Wheels Coupled Locomotive: Belgian State Railway.

The slide-valves are cylindrical with steam admission in the middle of the valve, which reduces the packing to simple bronze rings with lubricating grooves. The slack between each valve and the cylindrical chamber against which it rubs is closed by means of three cast-iron rings of suitable section, the steam pressing on the interior of the principal segment.

The oiling of the cylinders and valves is done by a lubricator in six sections. The lubricant used is a mineral oil with a high flash point.

The trials of these two locomotives took place with goods trains of accelerated speed and local passenger trains running on the Luxemburg line, the extremely undulating profile of which contains many inclines of 16 per 1,000.

Each locomotive worked twenty-four goods trains weighing 250 t. (246 tons) and twelve passenger trains weighing an average of 150 t. (147·6 tons). The total journey made by each engine amounted to 11,500 kilometres (7,146 miles). The saving of coal per train-kilometre in favour of the superheated-steam engine was found to be 13·33 per cent., and the water comsumption was reduced 18 per cent. On the other hand, the expenses of lubricating increased in a fixed proportion.

After four months of trials on the Luxemburg line, more precise experiments were organised with the through passenger trains on the Brussels and Charleroi line, which has a series of inclines of 13 per 1,000. For ten days, during which the climatic conditions remained invariable, these two locomotives hauled alternately the same train of 250 t. (246 tons). The saving in favour of the superheated-steam locomotive amounted to 12·5 per cent. for fuel and 16·5 per cent. for water. Moreover the speed raised at the top of the incline showed an average increase of 9·5 per cent., all the conditions being exactly the same.

As regards maintenance the superheated-steam locomotive, type 35, has not required special attention during its 1½ year's service.

These early favourable results have led to the Belgian State Railway venturing on the application of superheat to locomotives on a larger scale. With this in view twenty-five locomotives, comprising five different types, all provided with the Schmidt superheater described above, are actually in course of construction or are about to be put to work.

Amongst these last are a certain number of locomotives of type 35, which have fully confirmed the favourable results obtained by the first engine of this kind.

Among the number of services actually and successfully run by these engines is to be particularly noted the hauling, from Brussels to frontier, of express trains going to Paris. These trains, whose tare weight of vehicles exceeds 340 tonnes (334½ tons), surmount the 17 kilometres (10·56 miles) separating Mons and the frontier in 17 minutes, against a continuous up grade with inclines varying from 1 in 125 to 1 in 55.

Cockerill Superheater for Compound Locomotives.

It is seen from the preceding that it is now known that superheated steam as applied to locomotives is susceptible of giving remarkable results which come within the domain of practice. The State Railway has decided to persevere with their experiments in combining superheat with compounding, because they perceive that there is a most interesting question to elucidate.

Is it more economical to divide the superheater into two parts in such a manner as to raise the temperature at the entrance to both the H.P. and the L.P. cylinders, or, on the other hand, to devote the whole power of the apparatus to superheating the steam before it enters the L.P. cylinders? The Cockerill Company, after numerous investigations, have just completed a superheater that will enable them to settle this question.

This entirely new system is being continually tested on a series of compound engines, with four cylinders, and six-coupled wheels of 1·80 m. diameter (5ft. 10ins. diameter) with a bogie. This locomotive, called 19*bis*, possesses a boiler having an interior diameter of 1·65 m. (5ft. 5ins.) diameter, and is pressed to 15·5 atm. (227lbs. per sq. in.). The H.P. cylinders are inside and connected to the leading coupled-axle; the L.P. cylinders are outside and drive the second axle. The four cylinders are placed on the transverse axis of the bogie. The two valve motions of the Walschaert type are outside. They present several peculiarities due to the employment of cylindrical valves, with the steam introduced in the middle. The leading dimensions of the engine, type 19 *bis*, are shown in the table below.

Diameter H.P. cylinders	= 0·36	($14\frac{3}{16}$ins.)
,, L.P. ,,	= 0·62	($24\frac{13}{32}$ins.)
Stroke	= 0·68	($26\frac{25}{32}$ins.)
Initial pressure	= 15·5 atm.	(227lbs. per sq. in.)
Diameter of driving wheels	= 1·80 m.	(5ft. 11ins.)
Height—		
Rail to centre of boiler	= 2·80 m.	(9ft. $2\frac{3}{8}$ins.)
Tubes—		
Length of	= 4·0 m.	(13ft. $1\frac{1}{2}$in.)
Number and outside diameter	= 30 of 107 mm. = 219 of 50 mm.	($4\frac{7}{32}$ins.) ($1\frac{31}{32}$in.)
Heating surface—		
Interior of tubes	= 157·62 m².	(1,696·6 sq. ft.)
Of fire-box	= 18·35 m².	(197·5 sq. ft.)
	175·97 m².	(1,894·1 sq. ft.)
Area of grate	3·01 m².	(32·3 sq. ft.)

The apparatus for superheating the steam may be used in two ways. One may heat the steam near to the entrance to the H.P. cylinder, and afterwards near to those of the L.P. cylinders, or at the entrance to the L.P. only. The superheater shown in fig. 5 (page 9) indicates the general arrangement, comprising two series of large flame tubes containing the circulating pipes intended to superheat the steam.

The role of the compartments *C* and *H* is placed inside the barrel, and of the collectors *J* and *D*, installed in the smoke-box, will be dealt with later on in connection with the explanation of the working of the apparatus.

In B there is a valve with three pistons intended to divert the steam coming from the regulator towards the compartment C, or into the tube L, according as it is required to operate the superheat to H.P. and L.P. or to L.P. only. The movements of the valve B are automatically repeated, thanks to the presence in the tube L of an identically similar valve located within B^1. The destinations of the different pipes is made clear by following the course of the steam as explained below.

First Case.—Superheat at the entrance of H.P. and L.P.—The steam on leaving the regulator A makes its way, after passing B, towards the compartment C; from there it traverses the left set of superheater tubes and enters the collector D, whence it goes to the H.P. cylinders by passing through the valve B^1 and pipes E.

The superheated steam, after doing the work in the H.P. cylinders, goes out by the exhaust pipe, traverses the valve B^1, after that the pipe G, lodged in the interior of the barrel to enable it to enter the compartment H. From there the steam goes into the superheating tubes (the right set), and arrives by the pipes K leading towards the L.P. cylinders.

Second Case.—Superheat at the entrance of the L.P. Cylinder.—The valve B is placed by the driver in a position that diverts the direction of the steam, directly from the regulator into the pipe L; from there it goes to the H.P. cylinders after having passed through the valve B^1 and the delivery pipes E. On leaving the H.P. cylinders the steam traverses the pipes F, the valve B^1, and enters into the collector D. From the front it passes back through the left set of superheater tubes and arrives at the compartment C. From this it passes through the valve B into the compartment H, and traverses through the right group of superheater tubes, whence it goes into the collector J, and from there by the delivery pipes K into the L.P.

A locomotive of type 19*bis*, showing this pattern of superheater, is exhibited in the Liége Exhibition. Trials are going to be continued with a second identically similar engine, to determine which is the more advantageous mode of working to adopt for the new superheater.

It is manifest that if the superheat is required at the entrance of the L.P. cylinders only, it will be possible to dispense with a certain number of parts of the superheater and by that means remedy the obstruction in the spoke-box.

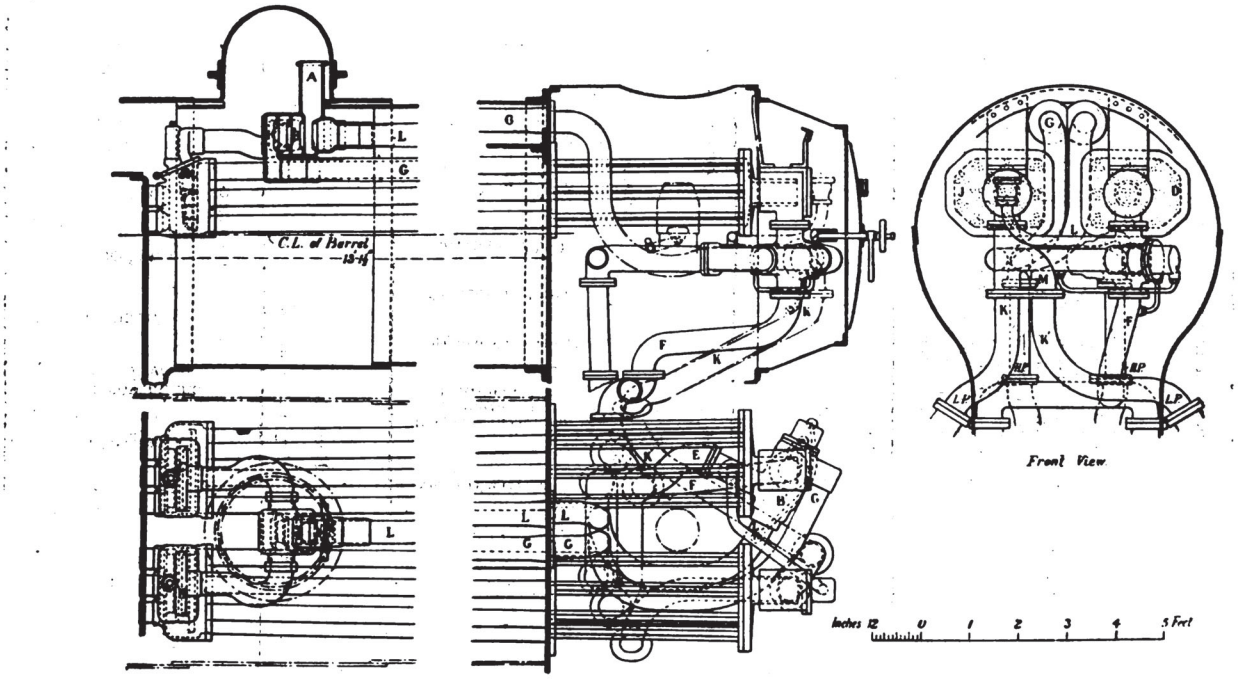

Fig. 5.—Experimental Superheater on a Compound Locomotive.

Railways and the Board of Trade.—V.*

(*Continued from p.* 146.)

ALL such occurrences, except broken tyres and axles, have to be reported on Form A, broken tyres on Form B, and broken axles on Form C. Copies of these three forms are annexed.

All accidents at level crossings to passengers, servants of the railway company and other persons, whether killed or injured, have to be reported with full detail on a special form, which for reference may be called Form D, and which is also annexed.

All these returns, accidents to trains and servants, and mishaps to road and stock, pass through the hands of the Assistant Secretary of the Railway Department and the Chief Inspecting Officer, who determine whether enquiries shall be held, or what further information shall be asked for from the railway companies.

As regards accidents to passenger trains, it may be taken that an enquiry is held in all cases where passengers are injured, or where there is revealed a breach of regulations, due to want of care on a servant's part or a lack of supervision on the part of officials.

Where the facts are quite clear and no good purpose can be served by an enquiry the case is dealt with by correspondence, or it is left to the inspecting officer to make some enquiries when next he is on the line concerned.

That only a percentage of the mishaps are enquired into will be seen by the following figures taken from the annual report for 1903:—

Year ...	1897	1898	1899	1900	1901	1902	1903.
Number of Accidents Reported—							
	188	168	291	299	276	223	235
Number of Enquiries Held—							
	48	58	66	64	44	37	31

Should an enquiry be ordered the company are not as a rule advised by the Board of Trade, and the first intimation they

* Nos. I., II., III., and IV. appeared in the *Railway Engineer* for January February, March and May respectively.