Proceedings of the Institution of Mechanical Engineers
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Superheaters Applied to Locomotives on the Belgian State Railways

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Proceedings of the Institution of Mechanical Engineers 1905 69: 409
DOI: 10.1243/PIME_PROC_1905_069_006_02

SUPERHEATERS APPLIED TO LOCOMOTIVES ON THE BELGIAN STATE RAILWAYS.

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(*Translated from the French.*)

The Belgian State Railways have 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. (5 ft. 3 ins.) while that of the cylinders is 520 mm. (20½ ins.). 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.

Under these conditions and in view of further increasing the power of the engines, it becomes necessary to have recourse 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 utilization of superheated steam is most economical. This is noticeable in hauling heavy goods trains on sections of the line having steep 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, permits running with early cut-offs, thus helping 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 States recognized 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 Herr 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.

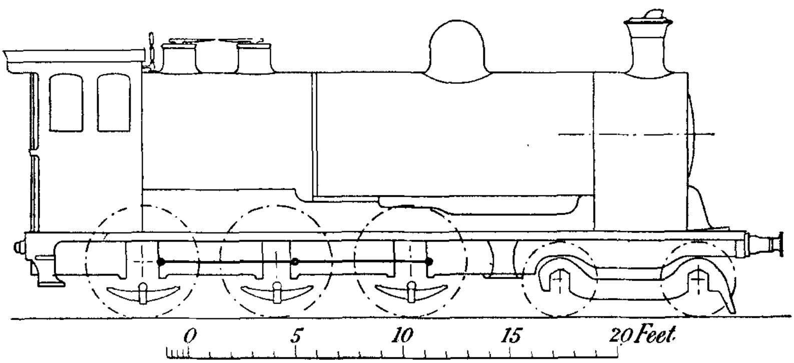
On the other hand, a superheater, placed in the barrel of the boiler and described later, Fig. 5 (page 417), offers some real advantages. It is lighter, less cumbersome, easier to clean and maintain, and its introduction does not necessitate any important modifications in the smoke-box. Consequently 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 utilization of steam slightly superheated does not offer any appreciable economy of fuel or increase of power.

On the other hand, with the Schmidt apparatus placed on a locomotive, type 35, Fig. 1 (page 412), and Plates 15 to 17, 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 1·600 m. (5 feet 3 inches) 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 train. The inside cylinders are made with piston slide-valves placed above, steam being admitted in the middle of

FIG. 1.—*Six-Wheels-Coupled Locomotive. Belgian State Railways.*



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 Fig. 1 and Plates 15 to 17.

The principal dimensions are given in the following Table:—

Cylinders:—	
Diameter	520 mm. (20½ ins.)
Stroke	660 mm. (26 ins.)
Working Pressure	14 atm. (205·8 lbs. per sq. in.)
Diameter of driving wheels	1·600 m. (5 ft. 3 ins.)
Height of centre of boiler above rail	2·650 m. (8 ft. 8 5/16 ins.)
Tubes:—	
Length	4·130 m. (13 ft. 6½ ins.)
Exterior Diameter	50 mm. (1 15/16 ins.)
Number	271.

Heating surface:—	
Interior of tubes	158·25 m.^{2} (1703 sq. ft.)
Fire-box	14·90 m.^{2} (160 sq. ft.)
Total	173·15 m.^{2} (1863 sq. ft.)
Grate area	2·84 m.^{2} (30½ sq. ft.)
Weight in running order:—	
1st Axle	9740 kg. (9·5 tons).
2nd ,,	9740 kg. (9·5 tons).
3rd ,,	18215 kg. (17·9 tons).
4th ,,	17850 kg. (17·6 tons).
5th ,,	17500 kg. (17·2 tons).
Total weight	72965 kg. (71·8 tons).
Adhesion weight	53565 kg. (52·7 tons).
Tractive effort $\frac{p\,d^2\,l}{D}$ =	16128 kg. (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. ($4\frac{5}{8}$ inches) diameter for 103 tubes of 50 mm. ($1\frac{15}{16}$ inches). For this locomotive the internal heating surface in the tubes is 98·10 m.^{2} (1,056 square feet), and the total heating surface is 130·056 m.^{2} (1,400 square feet).

The exterior superheating surface is equal to 27·15 m.^{2} (292 sq. ft.).

The superheater proper is illustrated in Plates 15 to 17, and consists essentially of two parts:—

(1) A series of iron tubes of 118 mm. ($4\frac{5}{8}$ inches) external diameter, occupying the upper part of the nest of tubes and offering like them a passage for flame and hot gases; and

(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.

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 gradients of 1 in 62.

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 kilomètres (7,146 miles). The saving of coal per train-kilomètre in favour of the superheated-steam engine was found to be 13·33 per cent., and the water consumption 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 gradients of 1 in 77. 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 years' service.

These early favourable results have led to the Belgian State Railways 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 (334⅝ tons), surmount the 17 kilomètres (10·56 miles) between 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 range of practice. The State Railways have decided to persevere with their experiments in combining superheat with compounding, because they perceive that there is a most interesting question to elucidate.

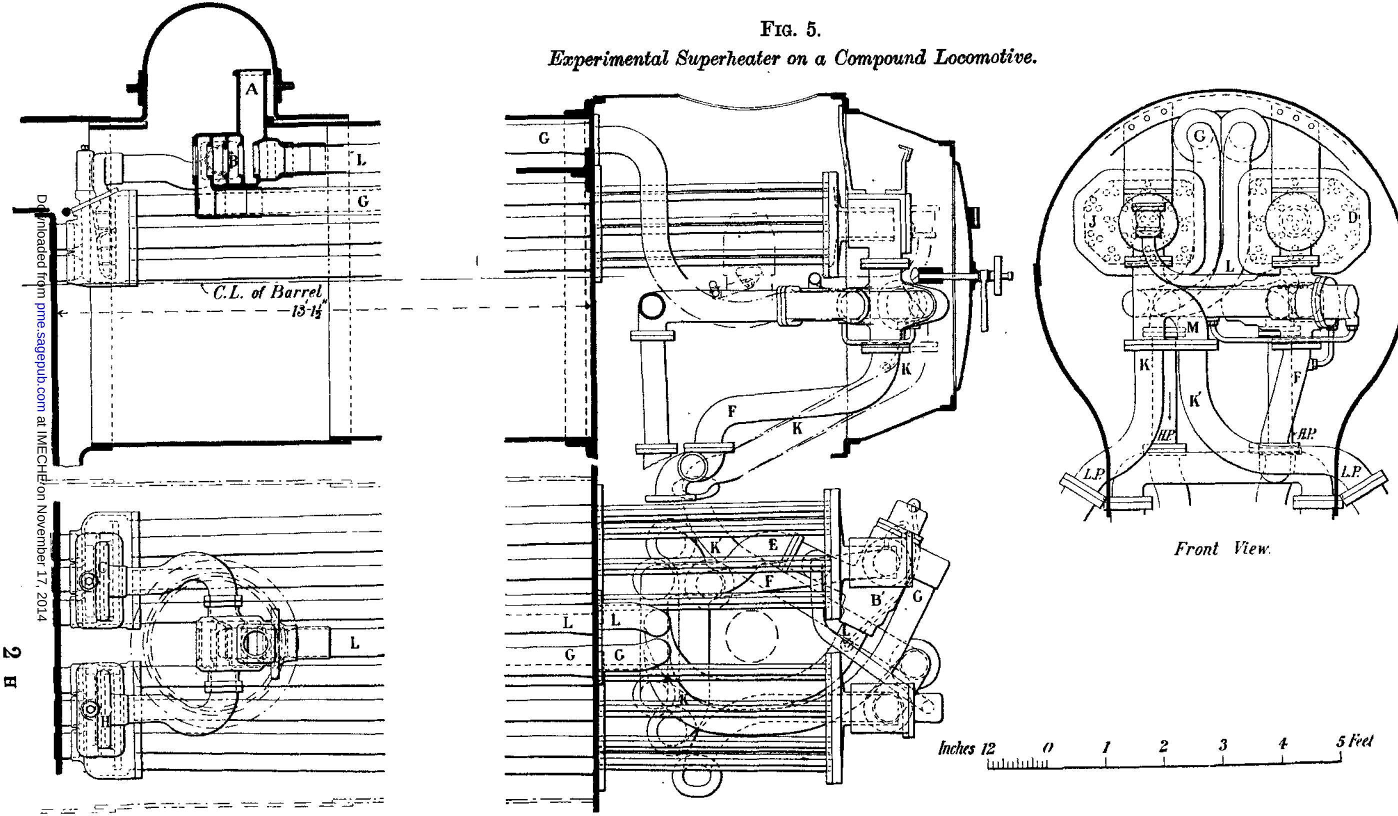
Is it more economical to divide the superheater into two parts in such a manner as to raise the temperature at the entrance to both the H.P. and the L.P. cylinders, or, on the other hand, to devote the whole power of the apparatus to superheating the steam before it enters the L.P. cylinders? The Cockerill Company, after numerous investigations, have just completed a superheater which will enable them to answer 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. (5 feet 10 inches) diameter with a bogie. This locomotive, called 19*bis*, has a boiler having an interior diameter of 1·65 m. (5 feet 5 inches) diameter, and carries a pressure of 15·5 atm. (227 lbs. per square inch). 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 Walschaerts 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	360 mm. (14 3/16 ins.)
„ L.P. „	620 mm. (24 13/32 ins.)
Stroke of piston	680 mm. (26 25/32 ins.)
Initial pressure	15·5 atm. (227 lbs. per sq. in.)
Diameter of driving wheels	1·80 m. (5 ft. 11 ins.)
Height, rail to centre of boiler	2·80 m. (9 ft. 2 3/8 ins.)
Tubes:—	
Length	4·0 m. (13 ft. 1½ in.)
Number and exterior diameter	30 of 107 mm. (4 7/32 ins.)
	219 of 50 mm. (1 31/32 in.)
Heating surface:—	
Interior of tubes	157·62 $m.^2$ (1697 sq. ft.)
Fire-box	18·35 $m.^2$ (198 sq. ft.)
Total	175·97 $m.^2$ (1894·1 sq. ft.)
Grate area	3·01 $m.^2$ (32 sq. ft.)

FIG. 5.

Experimental Superheater on a Compound Locomotive.



The apparatus for superheating the steam may be used in two ways. The steam may be heated near the entrances to the H.P. cylinders, and afterwards near to the L.P. cylinders, or at the entrances of the L.P. alone. The superheater shown in Fig. 5 (page 417) 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, 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, due to the presence in the tube L of an identically similar valve located within B^1. The arrangements of the different pipes are made clear by following the course of the steam as explained below.

First Case.—Superheat at the entrance to H.P. and L.P. Cylinders.—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 work in the H.P. cylinders, goes out by the exhaust pipe, traverses the valve B^1, after that the pipe G, which is 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 is conducted by the pipes K leading to 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. cylinder.

A locomotive of type 19*bis*, showing this pattern of superheater, is exhibited in the Liége Exhibition. Trials are about 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 smoke-box.

The Paper is illustrated by Plates 15 to 17 and 2 Figs. in the letterpress, and is accompanied by an Appendix.

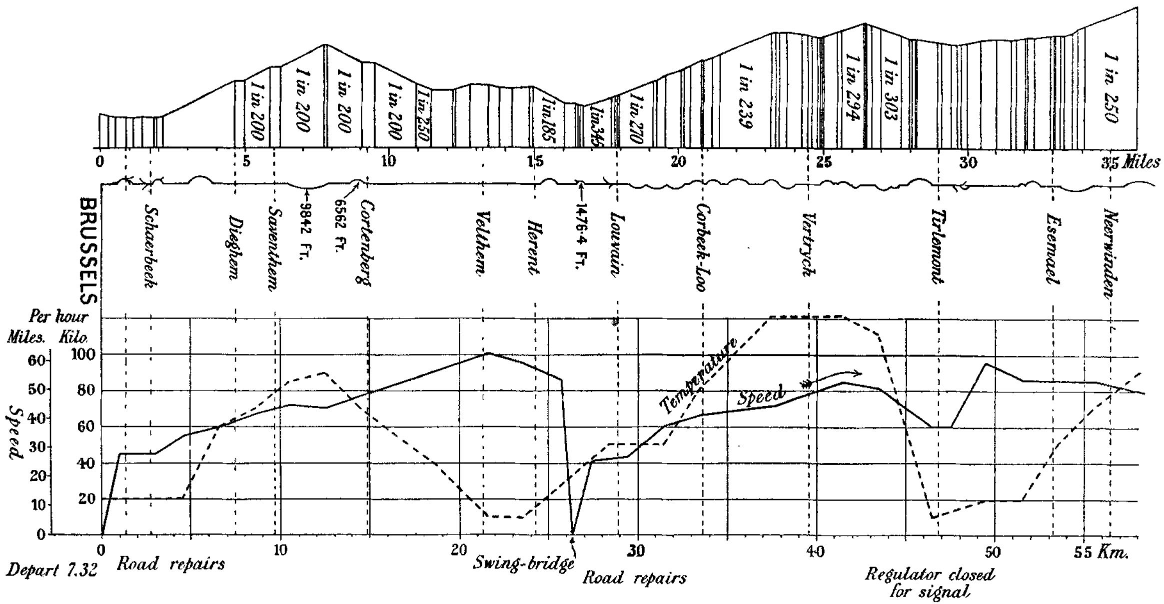
APPENDIX.

A diagram (Fig. 6, pages 420 and 421) shows the working of engine 3003, fitted with Schmidt superheater, on 31st May 1905, hauling a train of 327½ tonnes (322·3 tons), consisting of 11 carriages with three axles, one bogie carriage and two brake-vans of 3 axles, from Brussels to Ans, near Liége. The dotted line shows the varying temperature of the superheated steam. A full line shows the speed of the train, the grades and curves being given above these curves.

(*Continued on page* 422.) 2 H 2

FIG. 6.—*Steam Temperature and Speed Diagrams for Four-Cylinder Locomotive with Superheated Steam working from Brussels to Ans.*

Height of Ans above Brussels 525 feet.



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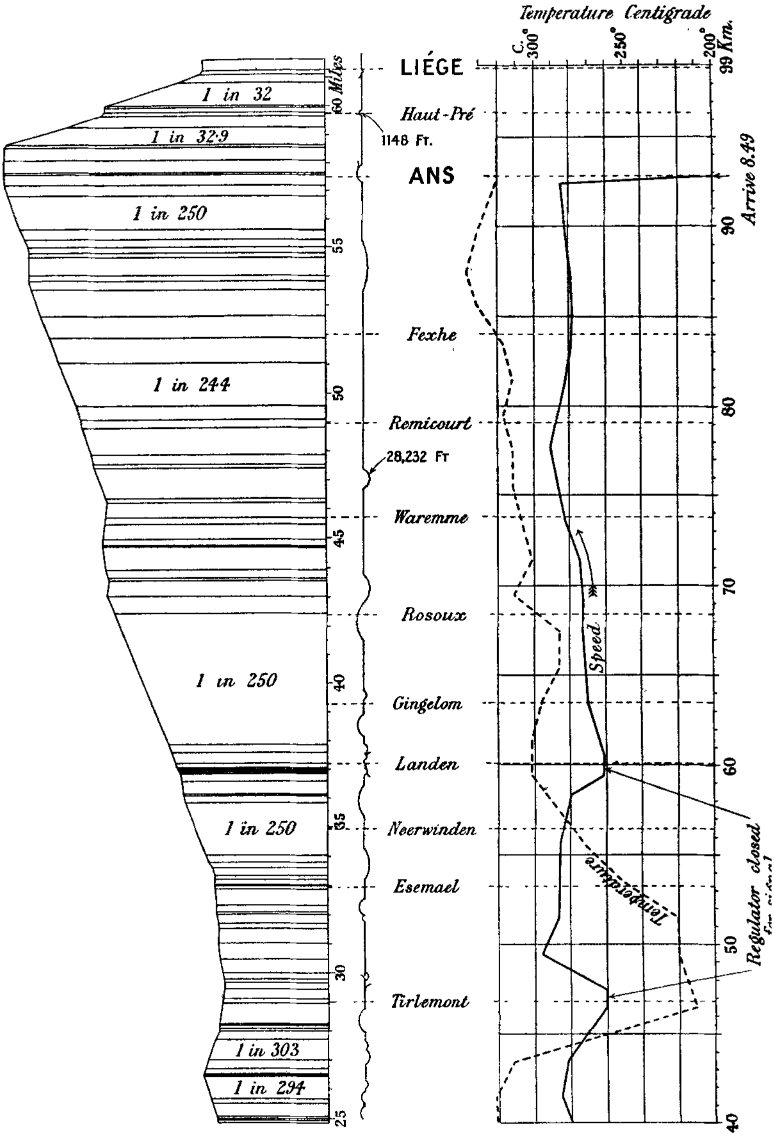

The principal dimensions of the locomotive are given in the following Table :—

Engine :	
Diameter of cylinders	435 mm. (17⅛ ins.)
Stroke of piston	610 mm. (24 ins.)
Number of coupled-wheels	6
Diameter of ,, ,,	1·98 m. (6 ft. 6 ins.)
Number of carrying-wheels	4
Diameter of ,, ,,	0·900 m. (2 ft. 11$\frac{7}{16}$ ins.)
Boiler :	
Length of barrel	4·000 m. (13 ft. 1½ ins.)
Diameter (greatest)	1·650 m. (5 ft. 5 ins.)
Thickness of iron plates	18 mm. ($\frac{23}{32}$ in.)
Fire-box shell-plate thickness	18 to 30 mm. ($\frac{23}{32}$ to 1$\frac{3}{16}$ in.)
,, copper plate ,,	18 to 27 mm. ($\frac{23}{32}$ to 1$\frac{1}{16}$ in.)
Tubes :	
Length	4·102 m. (13 ft. 5½ ins.)
Number and exterior diameter	25 of 127 mm. (5 ins.) 180 of 50 mm. (1$\frac{15}{16}$ ins.)
Thickness	3·5 mm. ($\frac{9}{64}$ in.) 2·5 mm. ($\frac{7}{64}$ in.)
Heating surface :	
Tubes (inside)	138·87 m.^{2} (1495 sq. ft.)
Fire-box	16·88 m.^{2} 181·7 sq. ft.)
Total	155·75 m.^{2} (1677 sq. ft.)
Superheating surface (outside)	38·95 m.^{2} (419·26 sq. ft.)
Grate area	3·01 m.^{2} (32·4 sq. ft.)
Working pressure	14 atmospheres (205·8 lbs. per sq. in.)
Tractive effort	$2 \times 0{\cdot}65 \times \frac{pd^2l}{D}$ kg.=10930 kg. (10·78 tons)

Discussion.

Mr. JOHN F. ROBINSON, Member of Council, was sorry the author was unable to be present at the meeting, because he would have been able to add some further information to that contained in the Paper, which would have made his communication even more interesting than in its printed form. Nevertheless the description of the Schmidt superheater and the forecast of what was going to be in the future were very interesting. The Schmidt superheater had been tried on a great many railways in different parts of the world, with somewhat varying success. He believed the Canadian Pacific Railway had had a great number of their engines fitted with it, and the officials were very much pleased with the result. On the other hand, the Cape railways had had two engines fitted with a somewhat similar contrivance to the Schmidt apparatus which had not proved satisfactory, the reason being, he thought, that the superheat arrangement was placed in tubes in the lower part of the valve. He believed there was only one large tube about 8 or 10 inches in diameter, containing a series of small U-shaped tubes, through which the steam was carried backward and forward inside the tube. For various reasons, partly due probably to the construction of the fire-box of the engine running on a narrow-gauge railway, he fancied the amount of gases which came through the lower tube was not very great, and therefore the effect of superheating was not obtained with that arrangement. On the Canadian Pacific Railway the tubes had been adopted arranged as shown in Plates 15 to 17. There were two rows of 4-inch tubes, or thereabouts, on the upper part of the boiler—three rows were shown in the diagram—and in that part of the boiler the superheating tubes were located. With that arrangement he believed they obtained a far better result, because the gases had a tendency to go along the higher rows of tubes.

With regard to the experiments carried out on the two different engines, the loads did not seem to be very great, and it would be very interesting to know what the actual consumption of coal was with the engines. The figures only gave the percentage in favour

(Mr. John F. Robinson.)

of the superheated steam-engine. Of course, in comparing the consumption of coal in different countries, the variation in the quality of the coal had to be borne in mind, but he thought a figure or two would make the subject more interesting and valuable. That remark applied not only to the first experiment mentioned, that on the Luxemburg line, but also to those on the Brussels and Charleroi line, where there was only 13 per cent. in favour of the superheated steam. With such a large engine, 246 tons could not be said to be a very heavy load.

It was interesting to note that the superheated steam locomotive had done exceedingly well in not requiring attention during a service of a year and a half—a fact which reflected very great credit on the builders. He noticed in the case of the engines referred to (page 415) that among the number of services actually and successfully run by the engines in hauling express trains from Brussels to the frontier and on to Paris, was one of 334 tons haulage over continuous gradients varying from 1 in 125 to 1 in 55. That was a very much better performance than those which had been referred to in the previous paragraphs of the Paper. He thought the experiment it was proposed to make with the superheating, either at the entrance of the low-pressure cylinder or divided between the low-pressure and the high-pressure, would be very interesting. In all probability it would be found desirable to do some superheating before admitting the steam into the high-pressure cylinders.

He noticed (page 416) that a new type of engine was spoken of, an engine with four cylinders and coupled six-wheels with a bogie and with the high-pressure cylinders inside and the low-pressure cylinders outside. That was exactly opposite to the De Glehn system, of which the members had heard so much from M. Sauvage a year or two ago.* The results in France with the De Glehn engines were exceedingly good, and it would be interesting to see how the two types of engine compared after working. The drawback seemed to be in having the large cylinders outside away from the centre line of the engine and the small cylinders on the inside

* Proceedings, 1904, Part 2, page 327.

nearer the centre line. He did not think the balancing of this new type of engine could be quite as good as that of the De Glehn engine. Superheating, speaking generally, had not been much utilized in England, partly because it was of more benefit to the compound engine than to the simple engine. Compound engines, with few exceptions, were not much in favour in Great Britain, but if superheating were introduced, he thought it would be probably found that the compound engine would very largely result from it.

Mr. MARK ROBINSON, Member of Council, suggested it would add to the value of the experiments in prospect if they were arranged so that the effect of superheating the steam before entering the high-pressure cylinder, without reheating between the cylinders, could be tried for the sake of direct comparison with the methods of superheating before entering both cylinders, or before entering the low-pressure cylinder only.

The PRESIDENT regretted very much the absence of the author, who was detained in Brussels in connection with his duties as Chief Engineer of the Belgian State Railways. Probably some of the members, after carefully studying the Paper, might have views which they wished to express, and the Secretary would be pleased to receive from them in writing any remarks they had to make. He was sure the members would accord the author a very hearty vote of thanks for his most able Paper.

Communications.

Mr. JOHN BARR wrote asking for further information on the following points:—

(1) How were the boiler tubes which contained the superheating ones cleaned; also how were the superheater tubes themselves cleaned?

(2) Was the regulation of the superheat left entirely to the driver? Would any damage be done if this regulation were neglected?

(Mr. John Barr.)

(3) Were the bushes shown in the glands and necks of the stuffing-boxes of gun-metal or cast-iron, as bronze was said to be "usually excluded"?

(4) Metallic packing. Were the *cast* rings mentioned on page 414 of cast *iron*?

(5) Why were bronze rings put in the piston-valves when this metal was said to be excluded?

(6) Was the extra cost of lubrication not such as would reduce the economy of fuel appreciably?

(7) Were cylindrical or piston valves a *sine quâ non* for superheated steam?

M. FLAMME wrote, in reply to Mr. John F. Robinson (page 423), that at the end of 1904 the Canadian Pacific Railway possessed 22 locomotives fitted with the Schmidt superheater placed in the boiler tubes, and on the Belgian State Railways there were now 31 locomotives with this type of superheater. The consumption of coal for each locomotive was not given, because it was a matter of making comparative experiments. It depended chiefly on the quality of the fuel used—a fact which was of no importance in the present enquiry, which dealt exclusively with the comparison of two locomotives of the same type, one with saturated and the other with superheated steam.

On the Brussels-Charleroi line (which has gradients of 1 in 77), the train-load during the trials was, for running purposes, fixed at 246 tonnes (246 tons). The gradients had to be taken with the greatest possible speed, and the time-table of the train reduced accordingly. The load of this train, drawn by the same locomotive, type 35, with superheater, has often exceeded 250 tonnes and at times reached 350 tonnes, on which occasions the whole power of the locomotive was employed in keeping the train to its scheduled time.

The new compound locomotives of the Belgian State Railways differed from those of the De Glehn system in the position of the cylinders. The low-pressure cylinders were placed outside instead of inside, and the four cylinders were also situated in line on the transverse axis of the bogie. In this way the connecting of the outside cylinders by a cross-stay (which would have made the examination of the top of the connecting-rod of the inside cylinders inconvenient) was obviated.

In reply to Mr. Barr's *questions* (page 425), the boiler tubes containing the superheater tubes were cleaned by the stoker by means of a jet of compressed air. The superheater tubes did not become greasy, because the steam was continually passing through them at a high velocity. The engine driver could regulate the admission of the superheated steam by means of a valve in the smoke-box closing the large tubes. If he neglected to work this valve, the regulator being closed, no immediate damage would ensue. If this omission were repeated very often, the superheater tubes would get out of order prematurely.

The metal used for the bushes in the glands and stuffing-boxes was cast-iron and not bronze, and the packing-rings of the piston-rods were also cast-iron. The piston slide-valves were provided with cast-iron rings. Bronze, however, could be used for the stuffing-boxes of the cylindrical slide-valves, because these, as already stated in the Paper, admitted the steam in the middle while the exhaust was at the ends; it followed, therefore, that the steam in contact with the stuffing-boxes was very little superheated. The extra lubrication expenses accompanying the introduction of the superheater were very small compared with the economy in fuel.

With regard to the type of valve used, it had been found that cylindrical slide-valves were especially suitable for use with superheated steam. It might be mentioned that the Belgian State Railways had applied these valves to numerous locomotives in which the steam was not superheated, and the results obtained were very satisfactory. It was absolutely necessary that the slide-valves should be of cast-iron; and that recourse should be had to a process of balancing, to be sure of having sufficient lubrication on the flat surfaces. The author was not aware, however, of an application of superheat to a locomotive with slide-valves.

SUPERHEATERS IN LOCOMOTIVES.

Pl. 15.

Fig. 2. *Six-Wheels-Coupled Locomotive. Fitted with Schmidt Superheater. Belgian State Railways. Cyls. 20½ ins. × 26 ins. Wheels 5 ft. 3 ins.*

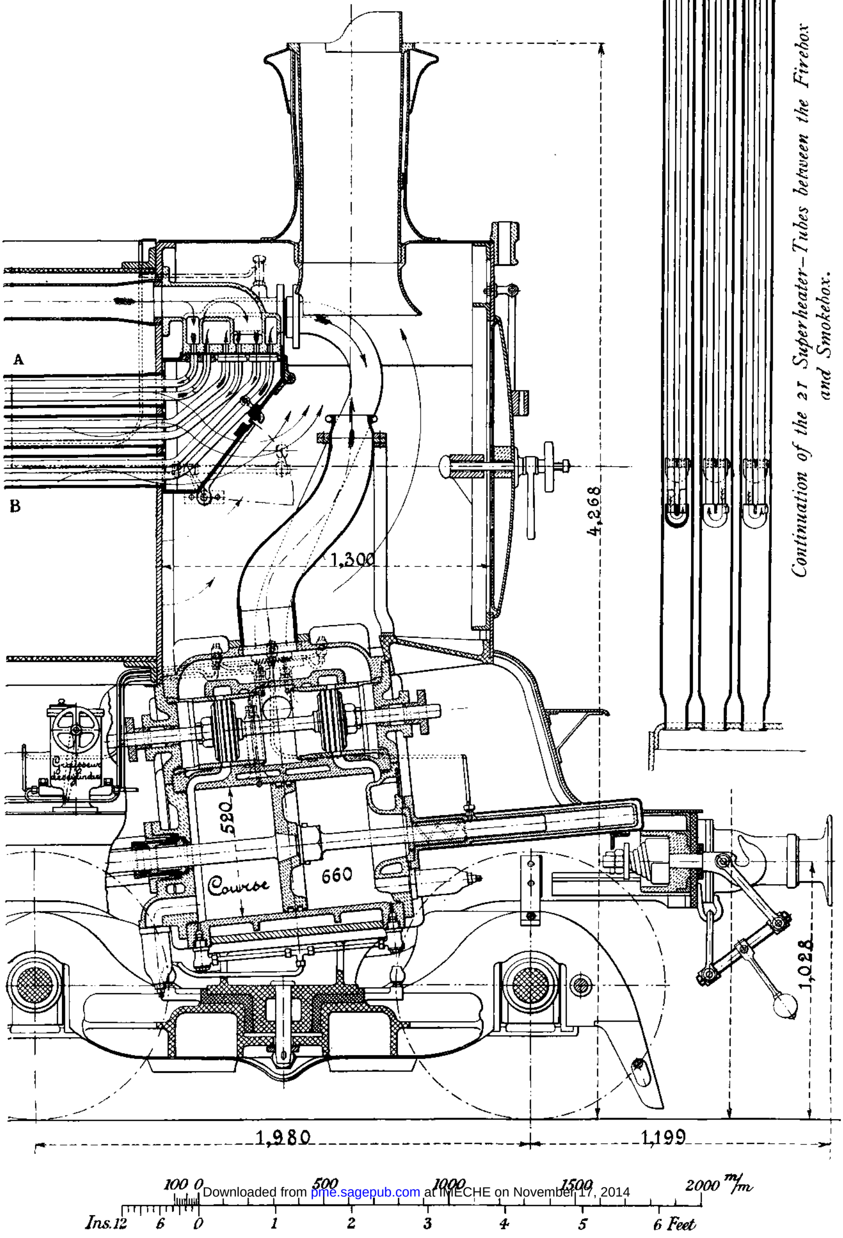

Fig. 3. *Six-Wheels-Coupled Locomotive.*
Fitted with Schmidt Superheater.
Belgian State Railways.
Section through Smokebox.

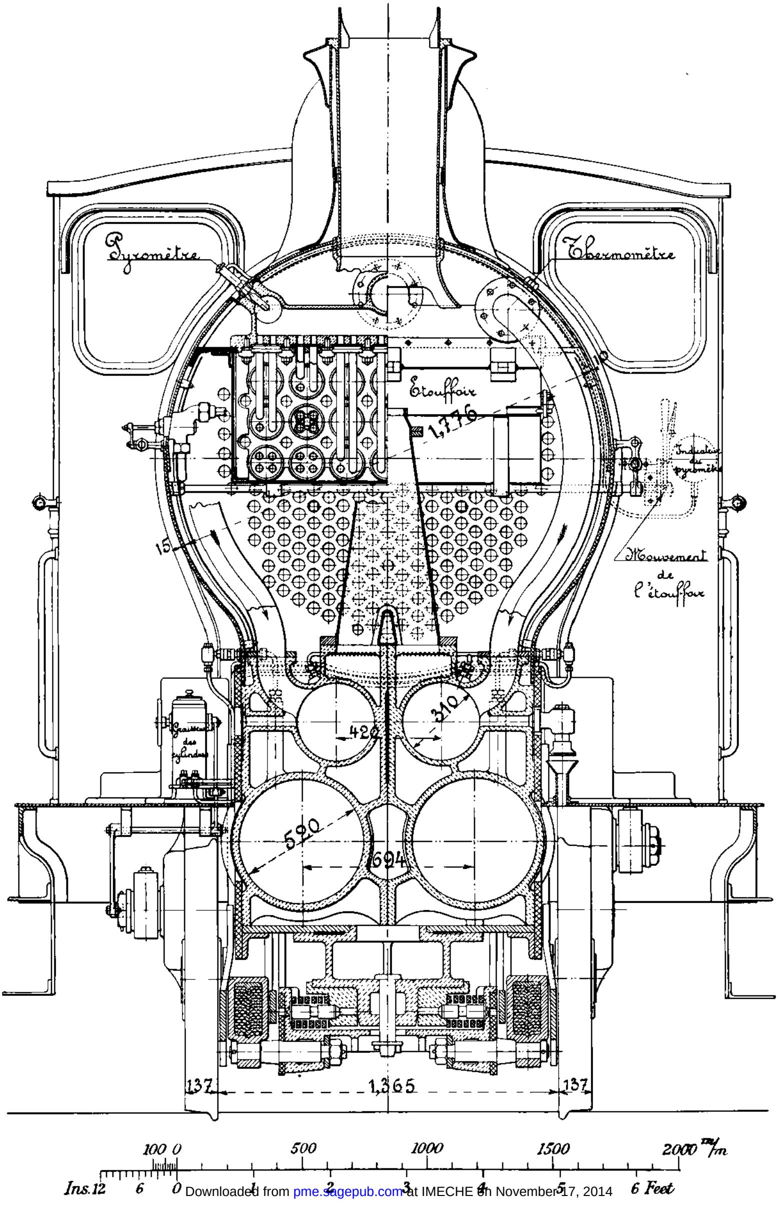

Fig. 4. *Six-Wheels-Coupled Locomotive.*
Fitted with Schmidt Superheater.
Belgian State Railways.
Section through Firebox.