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Chairman—Mr. G. H. BURROWS, A.M.I.Mech.E.

"COMPOUND LOCOMOTIVES & THEIR WORK,"

BY

J. C. CREBBIN.

THE AUTHOR asked the members to bear in mind that he was one whose business was not associated in any shape or form with railways or engineering. He had originally taken up the subject purely as a hobby, by designing, building, and testing experimental models, the result being that he had taken a particular interest in all locomotive work, and observations were made, when travelling, of the various types of machines used both in England and on the Continent.

The Author had entirely failed to obtain the coal consumption of the various engines that were mentioned in this paper, because each system measured the efficiency of their locomotives by different methods. However, the Author considered the De Glehn compound the most economical locomotive in coal consumption of all the types on the Continent.

The paper was almost entirely devoted to the four-cylindered compound locomotives of the Continent, because the principal English compound, namely, that on the Webb system, had proved itself inferior to very large numbers of simple locomotives now in use in this country.

As the ideas of compounding of those present were more or less wrapt up in "La France," the De Glehn Bousquet locomotive, belonging to the Great Western Railway, the history of the development of this system may be of interest. In 1885, when Mr. Webb's three-cylinder compounds had become a fair success, and a specimen had been built for the Western Railway of France, as was also done for the Pennsylvania railroad of America, M. Alfred de Glehn, Director General of the Locomotive Building Works at Belfort, designed a four-cylinder system of compounding for locomotives. It was first applied to an express engine, No. 701, belonging to the Chemin de Fer du Nord. This engine had four 6′ 10″ driving wheels, two high pressure cylinders, 13″ diam., and two low pressure cylinders, 18″ diam., the former being inside the frames, working the front pair of driving wheels, and the latter being outside, working the rear pair of driving wheels. At first, the engine ran without coupling rods, like Mr. Webb's three cylinder compounds, but, owing to the unequal strain put upon the locomotive when starting, coupling rods were soon fitted. The engine effected at once a saving of coal equal to 19 per cent., and after several years' service, was exhibited in the Paris Exhibition of 1889. Up to that time it had run 390,555 miles, and had realised a saving over the simple locomotive, performing identically the same work, of 2,260,720 pounds of coal.

Between 1876 and 1891 the fastest Nord trains were, with the exception of two locomotives, worked by a very fine eight-wheeled four-coupled type of engine, known as the "Outrance" Class, built in 1876, totalling in all 103 locomotives. With this type of engine, 150 tons behind the tender was considered a heavy load, and on the ruling gradients 1 in 200, the maximum speed with such a train did not exceed 40 miles per hour. Even, when later, the boiler pressure was raised from 134 to 148 lbs. per sq. inch, and the cylinders rebored to 18″ diam., these engines could not, with the allowance of any margin for bad weather, keep time with trains of more than 200 tons.

The experimental compound, No. 701, carried the same steam pressure, *i.e.*, 148 lbs., and was worked in turn; first, against the "Outrance" Class, and afterwards against a new type of simple engine, designed by M. Sauvage. The latter engine pulled 200 tons up banks of 1 in 100 at 45 miles per hour; but great trouble was experienced with the crank axle, owing to the excessive strain placed upon it. The compound, however, did better work with lighter repairs, and was cheaper in its coal consumption.

Therefore, it was decided by M. de Bousquet (who, at this period, had just been appointed locomotive superintendent of the Northern Railway) to build compounds of the De Glehn type in future for the Nord system. In August, 1891, the first of these locomotives appeared. They had four coupled wheels, seven feet diam., a bogie in front, with the order of the cylinders reversed, and were such a distinct success that several more were immediately ordered, and subsequently another forty of a still more powerful type. The first batch had 13½″ high pressure cylinders, and 21″ low pressure cylinders, by 25¼″ stroke, a total heating surface of 1671 sq. ft., and a boiler pressure of 199 lbs. per sq. inch, the difference in the subsequent types being in boiler power only; the second batch, having 1892 sq. ft. heating surface, and a steam pressure of 213 lbs. per sq. inch, the grate areas being increased from 21 to 28 sq. ft., while the weight was increased from 47 to 52 tons.

The De Glehn compounds constructed for the other French lines were practically the same as those just described, differing only in minor dimensions. Those on the Orleans line had slightly smaller driving wheels, 6′ 10″ diam., cylinders 13¾″ and 21¼″ respectively, and were fitted with a ten-brick heater in the firebox.

Those of the Midi Railway had the same size wheels as the Nord engines, but larger cylinders, like those on the Orleans Railway.

The Est Railway compounds had wheels 6′ 8″ diam., with the same size cylinders as the Orleans and Midi Railways, but larger boilers, having 1988 sq. feet heating surface and 228 lbs. steam pressure.

The Paris-Lyons-Mediterranée Railway locomotives had their standard driving wheels 6′ 6¾″ diam., and were developed by increased heating surface and boiler pressure only, the earlier engines having 1,594 sq. ft., and the later classes having 2,040 sq. ft. heating surface. All the express engines of this line were fitted with a prow, or wind cutter; an arrangement which the Author considered a very unnecessary appliance, because, with a strong side wind, it offered a greater resistance than the engines not so fitted.

The De Glehn six-coupled compound types ranged from 4′ 11″ on the Paris Lyon, 5′ 5″ on the Midi, and 5′ 9″ diam. wheels on the Nord, Est, and Orleans Railways; and the Author supposed that no series of engines in the world performed such wonderful work on any class of train, from express passenger to coal trains, as these locomotives daily accomplished.

Of the latest developments of the De Glehn compound, the first were similar to "La France," and were the "Atlantic" engines running on the Nord line. The second were the magnificent new Paris-Orleans "Atlantic" class, with 6′ 9″ driving wheels, cylinders $14\frac{3}{16}$″, and $23\frac{5}{8}$″ by $25\frac{1}{8}$″ stroke. Boiler heating surface 2,670, grate area 32 sq ft., and boiler pressure 225 lbs. per sq. inch.

The two engines recently ordered by the Great Western Railway were similar to the latter.

The new Ouest Railway engines had six-coupled wheels, 6′ $3\frac{3}{16}$″ diam., cylinders, H.P., $13\frac{3}{4}$″, L.P. $21\frac{5}{8}$″ by $25\frac{1}{8}$″ stroke, and a boiler having 2,174 sq. ft. heating surface.

The Est Railway had built some large six coupled bogie engines, with 6′ 10″ coupled wheels, cylinders, H.P. $13\frac{3}{4}$″, L.P. 22″ by 26″ stroke; heating surface of boiler being 2,671 sq. ft., and the grate area $29\frac{1}{8}$″ sq. ft.

This practically completed the development of the De Glehn compound in France. The arrangements fitted to these engines for starting purposes had all been described in a previous paper read before the Society. The work these engines were daily accomplishing was excellent, and the following results were taken haphazardly of some of their performances. One of the earlier types, starting from Calais with 260 tons behind the tender, ascended the eight mile bank of 1 in 125 to Caffiers, at a minimum speed of 41 miles per, hour. One of the larger batch of Nord eight wheelers, with 280 tons behind the tender, maintained 43 miles an hour up the same bank. Another, with the same type of engine, starting at the foot of a 12 mile ascent of 1 in 200, with 340 tons, attained 40 miles an hour in two miles, and steadily gained speed, until just before the summit the rate was 47 miles per hour; while up 1 in 250, a rate of 51 miles an hour was maintained. With lighter loads, of 180 and 200 tons, 60 to 62 miles per hour were maintained, up 1 in 200, and with 110 to 150 tons, 65 to 70 miles per hour was attained with ease. It would thus be understood that it was through the fine work uphill that the remarkable booked speeds in France were maintained.

These engines were never allowed by Government to exceed 120 kilometres (74·4 miles) per hour, unless, of course, special permission were obtained. Again, the Author had never seen an express train with a pilot engine in France.

The "Atlantic" compounds had entirely eclipsed the performances previously mentioned. A sister of "La France," No. 2641, took a load, exclusive of engine and tender, of 305 tons, from Paris to St. Quentin, 95¾ miles, in 90 minutes; averaging 62·1 miles per hour up the 13 mile bank of 1 in 200, also maintaining 74 miles an hour on the level and slight rise. On a special trial with one of these engines a load of no less than 360 tons was similarly dealt with.

The Nord express ran the distance, 95¾ miles in 96 min. 13 secs., the lowest speed at any point being 52·2 miles per hour on the 1 in 200 bank. When this was reached, the driver admitted high pressure steam into the low pressure receiver, so that the speed at the top of the bank had risen to 57·1 miles per hour. The total load was 468 tons.

Another of these engines, with a load behind the tender of 265 tons, maintained a speed up the Caffiers incline of 1 in 125, at an average speed of 61·8 miles per hour, and climbed 23 miles of 1 in 250, and 1 in 333, at 65 and 68 miles an hour respectively.

Of course, the only fair method of carrying out such tests was by means of a dynamometer car, and comparing the draw bar pull. Yet, when the De Glehn compounds had been tested in that manner, they had shewn excellent results. The Nord "Atlantic" compounds, for instance, recorded a pull of two tons at 70 miles per hour, and nearly 2½ tons had lately been recorded by one of the Paris Orleans "Atlantics" at the same speed.

With the six-coupled bogie class of engine, the Author had averaged 53 miles per hour, with 400 tons, from Boulogne to Paris, including two stops; and one of the same class was stated to have hauled 1,000 tons, on the level, at 38·5 miles per hour, and averaged 21·1 miles per hour up 1 in 200.

The next class of compounds most largely used on the Continent were the "Golsdorf" engines, of which some 1,400 were daily in use in Austria and Hungary. These engines were mostly of the two-cylinder type, the latest being a series of 21 ten-wheeled four-coupled four-cylinder compounds.

To understand the work of these engines, the nature of the line, gradients, etc., over which they had to work, must be appreciated. The permanent way was not well laid, and was one of the hardest lines in Europe. Therefore, it was difficult to compare their so-called express trains with the English fliers.

The following were the obstacles in the way of high speeds in Austria:—

1. The highest speed in any regular service was restricted, by laws of Government, to 90 kilometres per hour, *i.e.*, 56 miles.
2. When passing stations, where points diverged from the metals in the same direction in which the train was running, the speed must never exceed 60 kilometres, *i.e.*, 36 miles per hour.
3. The main lines contained frequent and very sharp curves of 380 to 450 metre radius.
4. Very long grades of 1 per cent. and more were met with all over the system.
5. The load per locomotive axle was restricted to 13 tons.
6. The fuel was of a particularly poor character; in most cases lignite, with an evaporative power of only four-fold, was being used.

When these drawbacks were considered, it would be understood why the Austrian engines could not start away with loads like English locomotives, more especially in consequence of their lack of adhesive power and the light fire on the grate; the result of this was that the timings of the fastest trains did not exceed 40 miles per hour from start to stop. The four-cylinder compounds averaged that speed between Vienna and Marienbad, and Vienna and Prague, with 240 tons behind the tender.

After leaving Prague, the line rose 1 in 100 for about 35 kilometres; and the average speed maintained on this grade was about 65 kilometres, or 38 to 40 miles per hour. This was very fine work considering the coal used, which costs about 3s. a ton. The Austrian fireman looked upon his English companion of the footplate with much envy, especially when he found his grate one mass of clinkers.

The longest distance run by these engines with only one stop was between Vienna and Budweis, 225 kilometres, about 130 miles. The longest distance without a stop being about 72 miles, between Vienna and Schwarbremen, with grades between these two points of 8 and 10 per cent. The heaviest loads taken by the four-cylinder compounds were, on the Southern Railway of Austria, between Vienna and Gloggnitz, where the express trains weighed 340 tons behind the tender. Between Neustatt and Gloggnitz there was a continuous up grade of 6·7 and 7·7 per cent. for 25 kilometres, about 15 miles. The average speed maintained over this distance being 60 to 65 kilometres, about 40 miles per hour.

As an instance of the manner in which different countries measured the coal consumption of their locomotives, in Austria they did not compare the engines by coal consumed, but by kilogrammes of coal per 1,000 tons hauled. The horse-power usually developed by these engines was about 1,250. The highest speed reached by them, with 55 tons behind the tender, was 140 kilometres, about 80 miles per hour, which Herr Golsdorf stated was maintained with perfect ease.

Before passing on to other systems, it would be interesting to note that Herr Golsdorf had carried out very careful experiments, comparing simple and compound locomotives. He had designed two locomotives exactly alike, with the exception that one was a compound and the other a simple engine, the results being as followed :—

1. A saving of coal from 10 to 20 per cent. by the compound.
2. Much greater horse-power developed by the compound, as a more uniform leverage power was given to the tread of the wheels, preventing skidding.

That the Golsdorf compound could start away quickly if required, was amply illustrated by the starting of the engines on the Vienna Metropolitan Railway, where the compound tanks employed made 3,000,000 starts a year, quite as rapid, if not better, than the engines on the Metropolitan Railway in London. The Austrian engines were painted black, with red fine lines.

The next series of interesting four-cylinder compounds were those running on the Italian Adriatic Railway. These engines possessed many novel features that were not to be met with in any other express engines in the world. They were ten-wheeled tank engines, designed to run cab first, in order that the driver may have an excellent view of the line ahead, and were designed by Signor Plancher, with large boilers of medium length, and with wide fireboxes and short grates. The arrangement of cylinders was very curious, the two low pressure cylinders were placed on the left side of the engine, one inside, and one outside the frames; the high pressure cylinders being on the right side, one inside, and one outside the frames. There were only two piston valves, one common to the low pressure, and one to the high pressure cylinders. The ports were crossed, so that each opposite end of the twin cylinders was always in connection, ensuring uniformity of pressure in the two cylinders and compensating for the irregularities of distribution, due to the varying angles which the connecting rods formed with their respective cranks. They all worked on to the same axle. The coal was kept in bunkers placed on each side of the engine, and water was carried in a cylindrical tender connected up to the back of the locomotive. The engines were, owing to the arrangement of cylinders, a little heavier on one side, but this had not affected their working.

The trains these engines hauled did not, as a rule, exceed 300 tons, yet they could average 50 to 56 miles per hour, notwithstanding gradients of 1 in 100 and 200. They worked fast passenger traffic between Roma Pisa and Genoa, where the grades varied from 1 to 100 to 1 in 83. The speeds were not high in Italy, so that it was difficult to judge the capabilities of these engines.

One of this type of engine was put to work on the Western Railway of France, and comparisons made against a De Glehn six-coupled compound. The Italian engine, with 260 tons behind the tender, ran from Le Maus to St. Lazare, Paris, including stops, 135·15 miles, in 192 minutes. This was not a brilliant performance after the work on the Nord Railway, but it must be remembered that the train was not timed to run faster. The result of the runs was that De Glehn proved to be the more economical engine. The Author had not had the opportunity of seeing these engines in daily work, so could not give any of their actual performances, but he had been assured lately that they could haul 500 tons at an average of 40 miles an hour.

With regard to the work of the various four-cylinder and two-cylinder compounds, and superheated simple locomotives in Germany, a separate paper would be required to do justice to the subject. Other than the De Glehn engines in Germany, the compounds on the four-cylinder systems were of two types, namely, Maffei and Von Borries. They were both of the "Atlantic" and ten-wheeled types; but all four cylinders, drove the front axle like the Golsdorf compounds in Austria; in fact, they resembled very much the Webb engines in England, save in arrangements of valve gear, and in the provision of much larger low pressure cylinders.

The Author did not believe the De Glehn engines were given an opportunity of fair comparison with these two types, inasmuch as the best work was always given to a "Maffei" or a "Von Borries" to perform. In fact, a German professor lately told him that when a railway was ordering some De Glehn "Atlantics" a short time back it was stated that the Company were only ordering the locomotives to prove the superiority of the other types. The Maffei "Atlantics" of the Baden State Railway hauled trains of 300 and 320 tons behind the tender, between Bâle and Maunheim, at an average speed of 56 miles per hour, and frequently reached 62 miles per hour actual running speed, which was the legal limit. They, however, were often bad in starting, having to reverse before getting away. This was due to lack of a good starting gear. The average amount of coal consumed per mile was 46·7 lbs. The 4-6-0 De Glehn compounds of that system, 83 in number, gave every satisfaction, but were only used for stopping trains and the express trains over the most difficult part of the system, between Offenburg and Constanz, where the speeds were not high.

The Alsace-Lorraine Railways had 85 passenger four-cylinder compounds, and were very pleased with their working. They were six-coupled bogie engines, with 6′ 1″ driving wheels, the boiler and cylinders being exactly the same size as on the "La France." On the trial of one of the first engines, a train of 406 metric tons (about 396 English tons) was hauled at 56 miles per hour, between Lautenburg and Strasbourg (55 kilometres) rising all the distance. With 350 English tons behind the tender, the average speed maintained was 62½ miles per hour. Water consumption, 2·2 gallons per indicated horse-power, per hour. Maximum horse-power indicated 1,630. These engines pulled all the heavy express trains from Bâle to Luxemburg and Strasbourg, and between Strasbourg and Avrincourt.

The 4-4-0 type were similar to the Nord engines, but the driving wheels were 78″ instead of 84″. There were 50 of these engines, chiefly employed in light express and passenger trains. The maximum legal speed was still 56½ miles per hour only; however, 72 miles an hour was reached by a special train a short time back with one of the six-coupled engines. As a rule, there were very few fine performances in speed on German Railways, as the legal limit was 100 kilometres, or 62·3 miles per hour, on the Baden and Prussian State Railways, and 90 kilometres on all the others. The trains weighed generally between 250 and 320 tons, and the locomotives employed were quite capable of dealing with these loads. The "Von Borries" engines ran trains at an average speed of 53 miles per hour, in spite of the limit of 56 miles per hour.

The Mallet goods engines were not generally to be recommended, because, although very successful in power and steam consumption, their cost of maintenance was rather high compared with ordinary eight-coupled goods engines. They should be used only in such cases where sharp curves were frequent and the track light, which required the weight to be distributed over a long wheel-base. These engines were, however, superior in every respect to a "Fairlie" or "Hagans" engine. The compound tank engines of the four-cylinder type used on the Ceinteur Railway of Paris were splendid starters, and attained a speed of 35 miles an hour in 40 seconds.

After observing the work of these tank engines, one felt ashamed of such eight-coupled tank engines as had lately been built for the Great Northern Railway of England; which had two cylinders, 20″ by 26″ stroke, and a boiler of only 1,100 sq. ft. heating surface. In consequence, although heavier than the French engines, the latter were obviously superior; and to any who had witnessed the work performed by the two types of engines, one could hardly say that compound tanks were a failure.

The Author had hoped to submit specimens of the coal used by the various engines on the Continent, but was only able to obtain a briquette, as used by the French Nord compound locomotives. When in Belgium, he visited the Charleroi coalfields, in order to see the coal used by the continental locomotives, for the benefit of this paper. The coal was found in seams of only a few inches thickness, and was always accompanied with about three times its own weight of dust. The lump coal was, therefore, too expensive for locomotive purposes. It was very amusing to see these lumps loaded into trucks, because each lump was lifted, carried, and very carefully placed in the truck by hand. When, by carelessness, a piece was chipped off the corner of one of these lumps, the foreman usually made some remark in Flemish, or some such language, to the culprit. The coal dust, or lignite, was of such a nature that it had to be washed in order to free the coal from foreign material; it was then filtered and dried, mixed with some tar refuse, then put into a large tank, where it was moistened by exhaust steam, and finally compressed by hydraulic presses into square bricks, better known as briquettes. It was this material that was used for steam production on the Continent. One could hardly compare it to the best Welsh coal used on the Great Western Railway of England; yet the very fine work performed by the French locomotives was obtained by the use of this material.

There was a system of compounding not yet tried in Europe, and one which was quite distinct from all other methods, viz., the Reikie system, invented by Mr. John Reikie, and applied to locomotives on the North Western Railway of India. The Author believed the arrangement was the outcome of the Directors ordering the enlargement of the existing locomotives when they were being re-built. In this system three cylinders were used, two outside high pressure of the same diameter as would be used for an ordinary single expansion locomotive, and one inside low pressure cylinder one and a quarter times the combined areas of the high pressure cylinders. For instance, to convert one of the "City of Bath" class of engines to a Reikie compound, the 18″ H.P. cylinders would be retained, a low pressure one of 28½″ diameter introduced, and the cranks set at an angle of 120 degrees. There would be no receiver, the exhaust from the H.P. cylinders going direct into the low pressure valve chest.

This type of engine seemed to answer every objection such advocates for the simple machine as Mr. Dugald Drummond made against the compound engine, for the object of this system was to make as much use of the expansion of steam in the high pressure cylinders as was possible in the simple locomotive, at the same time utilising the low pressure cylinder for a final expansion before exhausting up the chimney. The low pressure valve in this system always worked in full gear. Mr. Reikie had obtained very remarkable results, as much as 20 per cent. being gained over the simple engine for the same amount of fuel consumed.

The Author would like to see an engine on this system built for the Great Western Railway, and tests carried out between the De Glehn, Reikie, and "Albion" types of locomotive, and felt sure much would be gained by such comparison.

Mr. Reikie had, since his retirement (in conjunction with Mr. David J. Smith, of flash boiler fame) designed a somewhat remarkable locomotive, which may be of interest. It was a four-coupled bogie type of engine, having four single-acting cylinders, with mushroom valves. The cranks, connecting rods, and valve gears all ran in a case partially filled with oil. The boiler was of the flash type, having a heating surface of 2,000 sq, ft. Water was forced into the boiler by means of an automatic pump. It was arranged to keep a steady pressure of 400 lbs, per sq. inch; but, for starting purposes and for mounting heavy gradients, a pressure of 700 lbs. per sq. inch could be obtained by the movement of one lever. Should such an engine be built, its working would be very interesting to all concerned in locomotive work.

Having reviewed, very briefly, the work of a few of the compound locomotives employed on the Continent, an account of the Author's experiments with compound model locomotives (all $\frac{3}{4}''$ scale) may be interesting. First of all, a single expansion model was built, with 1″ bore by $1\frac{3}{8}''$ stroke cylinders, which were lined down to $\frac{7}{8}''$ and $\frac{3}{4}''$, the results of each alteration being carefully noted. The model was then re-built as a two cylinder cross compound, with a starting valve attached. The efficiency from the alteration was very marked, as a gain of at least 10 per cent. for the same consumption of fuel was obtained. On a trial made with the model in Belgium, a mean speed of 10 miles per hour was recorded, whereas the highest mean speed ever recorded as a high pressure engine was eight miles per hour. The next series of experiments were carried out upon an Atlantic type model with no less than three sets of cylinders. The first being high pressure; the next tandem compound cylinders, with piston valves; the next with balanced slide valves without steam chests; and the final experiment was with the present D valves. The boiler was also of great interest, as many types of water tubes had been tried in order to obtain a really suitable water tube for locomotive purposes. First of all, "Field" tubes were fitted, then plain vertical tubes, and finally with tubes having one end sealed, and divided into two parts for circulation by means of a division plate, one side of the tubes being higher than the other. In these tubes, the circulation of water was not only very rapid and perfect, but allowed of a lower water level being carried than any other vertical water tube would permit. This was the result of a series of very careful experiments and observations being made with glass tubes. Finally, a boiler containing these tubes only, with a heating surface of 180 sq. inches, was built, in conjunction with Mr. Bryant, of Cowes. The results being that with the same burner and on the same consumption of fuel it created more steam than a boiler of the locomotive type, having 300 sq. inches heating surface. It would, therefore, be understood that circulation of water in a boiler was a matter of vital importance.

The model, in its present state, gave a horse-power of one-eighth, whereas, previously, one-ninth horse-power was the utmost ever attained. These tests were carried out by Professor Westlake. This was a gain of about 15 per cent. on the same consumption of fuel. This model seemed to the Author to be a very suitable design for main line traffic, as it was simpler than any other type of four-cylinder compound. The engine was designed so that the low pressure valves could always be working in full gear, while the high pressure valves could be worked expansively at the will of the driver. Again, by means of a small valve, high pressure steam could be admitted into the low pressure cylinders for starting purposes. These arrangements were not fitted to the model because the Author never found any difficulty in starting the model.

The next model the Author intended to build and experiment upon was a six-coupled type of engine after the De Glehn system, with the exception that while the high pressure cylinders had a short stroke, and the valves could be worked expansively, the low pressure cylinders had a long stroke, and valves arranged to work in full gear; in fact, the engine was to be a combination of a "La France" and "Albion." It may be that some day they would be able to view this engine at work, and compare it with the existing models.

In summing up this paper, the Author wished it to be understood that at one time he was much prejudiced in favour of the simple expansion locomotive, and was only converted by observing the exceedingly fine work accomplished by the compound locomotives of the Continent. At the present time, there were no more single expansion engines being built for use in Germany, France, Austria and Switzerland.

The failure of the compound engines in England was to be attributed to several causes, but the chief reason may be said to be that all the systems used or tried were obsolete. The cylinders of the Webb compounds were so badly proportioned that one could only wonder their performances had not been worse.

The North Eastern compounds (two-cylinder type) seemed to have been better, but the relative adjustment of the high pressure and low pressure valve gears might have been greatly improved upon. The blast pipes for compound engines (and even this was to be noticed in model compounds) must be designed very carefully.

The first German two-cylinder compounds were far from successful; but they had been carefully studied and steadily improved upon and fitted with modern starting valves, so that there was now no mistake about their decided superiority over the simple engine.

The Author had hoped to have given a better illustration of this, but owing to an illness he had had at the latter part of last year he had been unable to visit Germany and obtain the particulars required.

Three-cylinder compounds gave an excellent turning effort, and so far as balancing was concerned they could be balanced perfectly in fore and aft motion, but when working expansively they were no better than engines with two inside cylinders.

In the four-cylinder engine balancing could be perfected, and by transmitting the power over more than one axle a steady running machine was obtained. To those who maintained that the compound was no better than a well designed simple engine, the Author could only ask them to travel and observe, and he felt sure the sceptic would be convinced as to the superiority of the compound locomotive over the present single expansion machine.

In conclusion, the Author apologised for being unable to illustrate all the types mentioned in this paper. He wished to thank M. Sauvage, Herr Goldsdorf and Mr. Moore for their help in obtaining details, and for the loan of several of the illustrations. He was also sorry that the subject had been one that, in the short time at his disposal, could not be treated with that just consideration it deserved.

With regard to the reports that "La France" was little or no better than "Albion," this by no means proved that the simple engine was equal to the compound, for the following reasons:—

1. Because "La France" was as yet new to the Great Western Railway. The drivers, for instance, were not thoroughly acquainted with an engine of that type, and, therefore, had probably not obtained the best results possible from the locomotive.
2. The boilers of the two engines were different. According to the English method of measuring heating surface the "Albion's" boiler was much the larger. The Author believed this boiler to be the better steam generator; therefore the compound was working at a disadvantage.
3. The firebox of the "Albion" was more shallow than that of "La France," which was very deep. The former provided a better circulation round the firebox, and, in consequence, less trouble was experienced with the stays; whereas, in the deep box, with a fierce fire and inadequate circulation, burnt stays and a leaky firebox were the results.
4 It must be borne in mind that "La France" had had to try conclusions with the most scientifically designed simple locomotives yet constructed, and, therefore, results must not be expected which would be apparent if the compound had to run in conjunction with other simple engines.

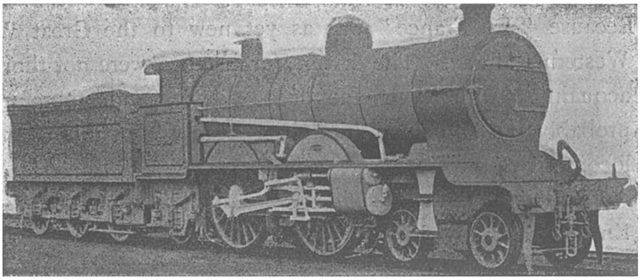
The Author would like to suggest that the only method to determine the success or non-success of the compound locomotive on the Great Western Railway would be to fit "La France" with a boiler similar to that used on the "Albion," and he felt sanguine that a marked increase of power in favour of the compound engine would be the result.

In ordinary fast running the De Glehn engine should be linked up as follows:—

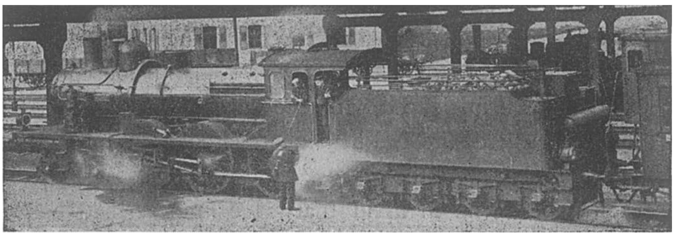
35 per cent. for the high pressure cylinders.
70 per cent. for the low pressure cylinders.

For very fast running with light loads the low pressure gear could be linked up to 75 per cent.; but the above positions were the best, and according to the power required the regulator should otherwise be opened or closed.

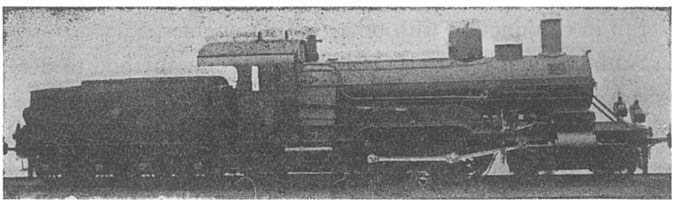
The following illustrations showed the principal Compound Locomotives in use on the Continent:—



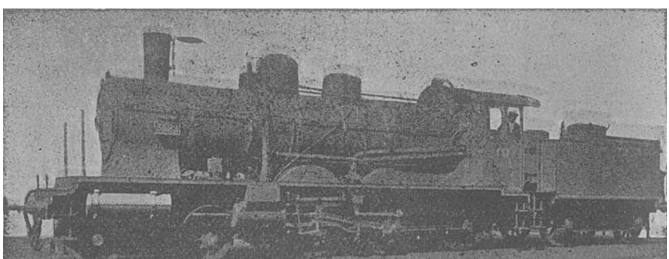
Latest type of De Glehn Compound. Built by the Vulcan Foundry Co. for the G.N.R. Co., and doing very good work.



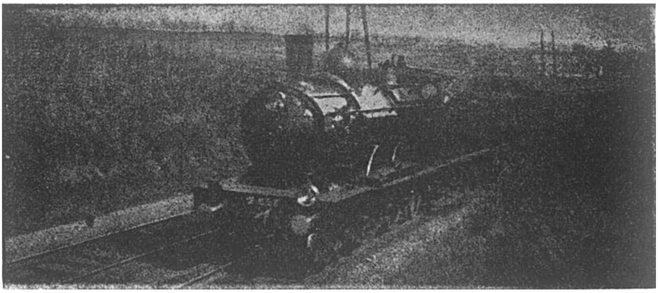
4.6.0 De Glehn 4-Cylinder Compound Express Engine for the Alsace-Lorraine Railways of Germany and Baden State Railways.



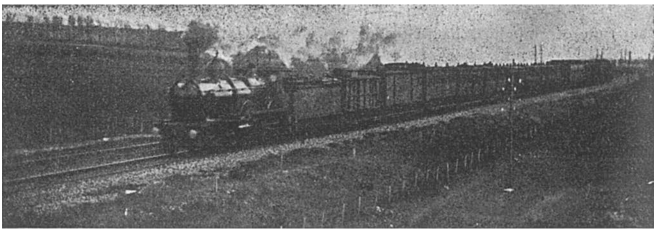
Von Borries "Atlantic" 4-Cylinder Compound for Prussian State Railways. One set of motion worked the two valves. The L.P. valve was arranged to give a later cut-off.



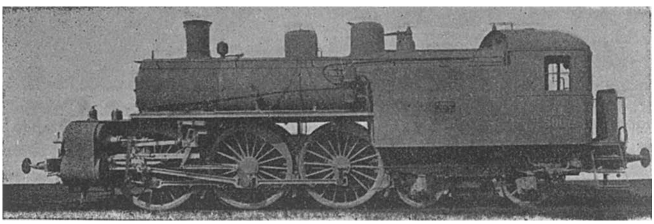
Eastern Railway of France 4-Cylinder Compound 5ft. 9in. coupled wheels. This illustrated the standard 4.6.0 locomotive of France. The new 6-coupled for this line were simply an enlargement of this type.



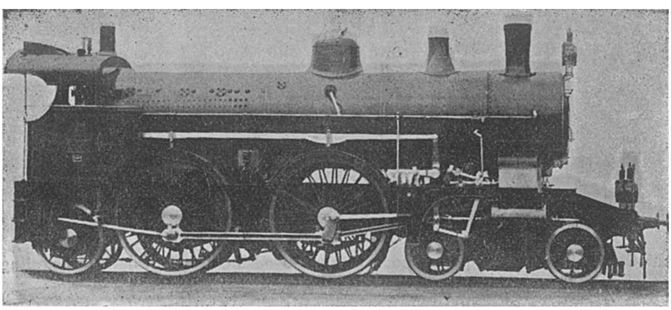
Nord Express at 70 miles per hour between Calais and Paris. The engine is a 4-Cylinder Atlantic Compound, similar to the G.W.R. "La France."



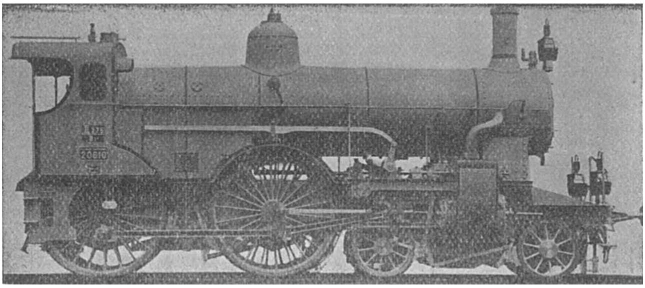
Paris to Calais "Flier," hauled by last class of 7ft. 4.4.0 type 4-Cylinder Compound, with bogie Tender. This illustration gives an idea of the length of ordinary Express Trains.



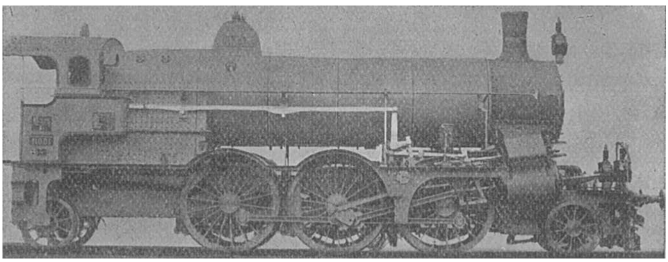
Adriatic Railway of Italy 4-Cylinder (Tank) Compound, used on the Express Services between Rome, Pisa and Genoa. These engines run cab first.



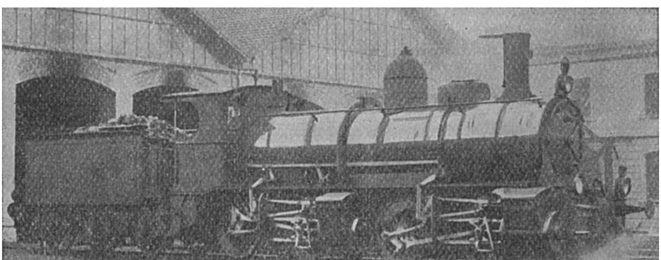
Golsdorf 4-Cylinder Atlantic Compound, used between Vienna and Marienbad.



Latest type of Standard 4.4.0 Golsdorf 2-Cylinder Compound for the Austrian State Railway. The long bogie was fitted to prevent more than 13 tons being placed on each axle of the coupled wheels.



Golsdorf latest type of 4-Cylinder Compound, having wide-type firebox and taper boiler. Built to haul the heavy expresses in Austria.



Mallet Standard 4-Cylinder Goods Engine, used on the Continent for hauling heavy goods trains over steep grades with sharp curves.

DISCUSSION.

THE CHAIRMAN said he was glad to hear that the performances of the De Glehn engine proved it to be the best engine on the Continent, and would like to know if Welsh coal was used on the French railways. He remarked that Joy's valve gear appeared to be adopted on most of the Continental engines.

Mr. R. H. SMITH said he had heard a paper on very much the same lines as the Author's some twenty years ago, and the opinion he then formed with regard to compound locomotives had not changed very much. In that paper it was stated that 20 to 25 per cent. could be saved by working compound, but he (Mr. Smith) had not found it so. At the same time there were other points to be considered. He had found the French compound "La France" to be a well balanced and smooth running engine; but he was very much disappointed with the general results. The G.W.R. "City" class would take a train of 200 tons from London to Bristol in two hours, whereas "La France" only saved two lbs of coal on the same performance. Welsh steam coal of the best quality was used for both engines. The boiler of "La France" would maintain steam with a load of 220 tons. To enable this engine to take a dining car train, consisting of ten eight-wheeled corridor carriages, approximately 300 tons, from Exeter to London, with one stop, it was necessary to use best steam coal and to keep up full steam pressure the whole of the distance, which included a rising gradient of 1 in 1625 for 20 miles, and another gradient of 1 in 115 for 2½ miles. It would not do, however, to depend upon the running under such conditions, for it was found a most difficult matter to maintain full pressure of steam in the boiler, even with the most careful firing. If, in running the non-stop train from London to Plymouth the boiler pressure were to drop, with a load of 300 tons, it was necessary to attach another engine, which was not satisfactory. The "Albion" was superior to "La France" in that it possessed a better boiler; and, in fact, he considered the former to be a better engine in every way.

THE AUTHOR, in replying, said some of the trials of the Continental compounds were made with Welsh coal. Joy's valve motion was not used extensively on the Continent, for better results in expansion had been obtained with the Walschaert valve gear, which was outside, and more easily examined, etc. With reference to the comparison of G.W.R. engines, "Albion" and "La France," the Author thought that if the latter engine had been built with the "Albion" boiler the results would be altogether different, and he felt certain the engine would do much better. The new engines which the G.W.R. had on order from France would be more satisfactory, as the heating surface of the boilers was considerably increased. Yet, in the opinion of the Author, these boilers would not make as much steam as the "Albion" type, because the serve tube was not much better than the ordinary plain type.

In the Author's opinion it was not fair to compare the acceleration of a 6-coupled loco. with a 4-coupled engine.

At the conclusion of the discussion the Author submitted several working models for the examination of the members.