

FORCED LUBRICATION FOR AXLE-BOXES.

BY MR. T. HURRY RICHES, *President*,
AND MR. BERTIE REYNOLDS, OF THE TAFF VALE RAILWAY, CARDIFF.

This Paper describes a system of Forced Lubrication as arranged for the driving axle-boxes of some of the steam-cars of the Taff Vale Railway Company. Before entering into a detailed description of the system used, it will perhaps be advisable to give a few of the more necessary particulars concerning these cars.

The engine is carried on a four-wheeled truck of 9 feet 6 inches wheel base and 2 feet 10 inches diameter wheels, the boiler (of double-ended locomotive type, lying transversely across the frame) being placed immediately over the centre of the leading or driving-axle. The front end of the coach is supported by means of a bogie centre, carried between the frames at a distance of 4 feet from the trailing-axle, or 5 feet 6 inches from the leading-axle. When the car is loaded with its full complement of passengers, the weight on the driving-axle is 15 tons 13 cwt., the weight at the rail being 17 tons 6 cwt. The journals are 6 inches diameter by $9\frac{1}{2}$ inches length; therefore the pressure, taking two-thirds of the projected area of the brass as bearing area, is 466 lbs. per square inch, the number of the revolutions of the journal, at a speed of 30 miles per hour, being practically 300 per minute. With this pressure and high rubbing

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velocity an undue amount of oil was being used with the ordinary method of lubrication, while cases of the bearings running hot were not infrequent, therefore the following arrangement for lubricating the journals under pressure was adopted.

To a cross-stay in front of the driving-axle, Fig. 1, a small gun-metal tank of rectangular section, Plate 16, is fixed. On the side of this tank, nearer the driving-axle and in connection with the tank, two small rotary pumps—right- and left-handed—are fitted, the one for forward running and the other for backward running. These pumps are driven directly from the driving-axle by means of a belt passing over a flanged pulley carried midway between the pumps, the pulley containing on each side of it a roller-clutch, somewhat similar to a free-wheel arrangement, fixed to the driving-spindle of the pumps. By these means, the one belt drives either pump forward or backward, the other pump being free.

Following the process through, for the lubrication of one of the journals, when the car is in motion, oil is pumped from the tank and forced through a coiled copper pipe to the top of the axle-box, Plate 17. An oil channel, $8\frac{1}{4}$ inches long, $\frac{1}{8}$ inch deep, is cut in the crown of the box, leaving a margin of metal at each side of the channel of $\frac{3}{8}$ inch flat, which is found, when the box is properly bedded to the journal, to be quite sufficient to ensure that it shall be perfectly oil-tight at the pressures attained.

After passing round the journal, the return oil is collected in the axle-box keep, and from there is brought back to the tank by means of a flexible pipe which allows for the rise and fall of the axle-box, care being taken that the reservoir into which the oil is returned is sufficiently below the keep to drain it. At each side of the axle-box keep a half-ring is fitted with bearing area about $\frac{3}{8}$ inch wide. These half-rings are bedded well to the axles, and are supported upon a couple of small coil-springs which hold the rings up to the journal with a fair pressure, and so prevent the escape of oil along the journal on the bottom side. The supply tank is so arranged that the return oil, after draining from the keep into it, shall pass through a filter before being again sent through the pump. Such briefly is a general description of the method adopted.

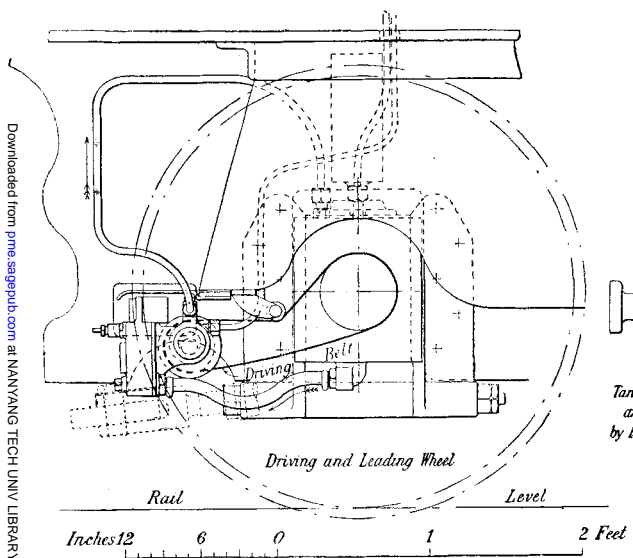
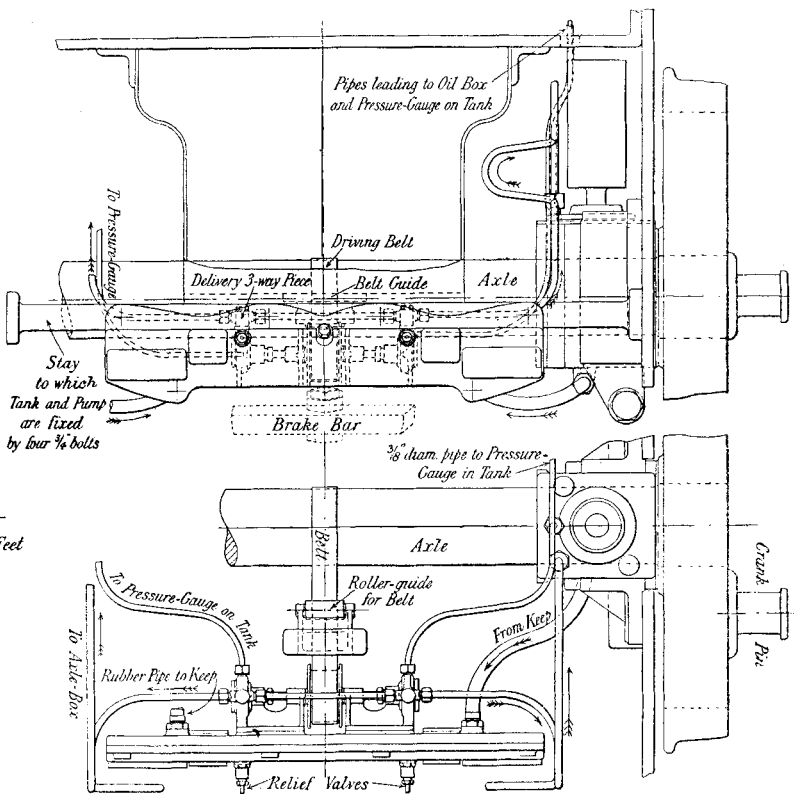


FIG. 1.

*Forced Lubrication applied to Driving Axle-Box
on Taff Vale Railway.*

Many points arise however in regard to the working of the arrangement which it will be well to explain. In the first place, the pumps when running fast (at a speed of 30 miles per hour, the revolutions of the pump are 440 per minute) deal with a greater quantity of oil than can be accommodated in the circuit at a pressure of, say, 20 lbs. per square inch, above which, in practice, it has not been found advisable to work. A relief valve is therefore fitted to each pump with an adjustable spring which enables the pressure at which each pump shall work to be regulated. The excess oil, when pumping, simply passes back into the tank again, through the relief valve against the pressure of the spring. A small pressure-gauge connected to each pump, and fixed in the driver's cab, shows the pressure of the oil pumped on both forward and backward running, whilst also acting as an indicator should failure of either pump occur at any time. Should this happen from any cause, the ordinary system of lubrication, by means of a lubricating-box in the cab, is at hand. This lubricating-box is also necessary, to enable oil to be put into the axle-boxes after the car has been standing for a day or two, and so avoid starting away with dry axle-boxes.

To prevent the oil from the running pump flowing into the other pump and causing it to run backwards, a small ball-valve is placed in the three-way piece leading from each pump to the circuit. The movement of the axle-boxes relatively to the tank and pumps was met in the first instance by trying different sorts of flexible piping, but finally, ordinary coiled copper piping was adopted, both on account of its comparative durability and of its accessibility at any time.

The belt drive for the pumps at once gives a simple method of driving and one which allows for a small relative motion of the axle and pulley. It is apt, however, to soon become saturated with oil, and then slipping occurs. An occasional application of one of the various belting mixtures, however, greatly reduces this slipping. When equal relief-valve springs were put in, it was noticed that the pressure indicated for forward and backward running varied considerably, probably due to the difference in the slip of the belt

in each case. The filters in the tank are removable, and are taken out and cleaned at the end of each day's work, the oil being first drawn off through the stop-plug, the thicker part of the oil, after straining, being then replaced by a small supply of fresh oil.

The foregoing description shows one method of dealing with an everyday problem in connection with the running of railway motor-cars, or any rolling stock in which the pressure on the bearings, combined with the rubbing velocity, is excessive. The matter is one of importance to all concerned in the design and care of such stock. This short Paper has been written in the hope that it may be useful to some investigators of this subject.

The Paper is illustrated by Plates 16 and 17 and 1 Fig. in the letterpress.

Discussion.

On the motion of the PRESIDENT, a hearty vote of thanks was accorded to Mr. Bertie Reynolds for his Paper.

Mr. WILLIAM H. ALLEN, Member of Council, in opening the discussion, said he had known the President for the past half-a-century and had never had to find fault with him before, but he did so on the present occasion. The President and his colleague had brought forward a most engrossing theme for discussion, but had stopped short at a description of the drawings, no results being given. He hoped that, in reply to the discussion, the authors would be able to state what results had been achieved, as he believed the present was the first time forced lubrication had been used on rolling stock. His own connection with forced lubrication was rather an interesting one, and the members would, he hoped, forgive him if he told them a little history. Sebastian Z. de Ferranti when he was a boy, in 1881, asked him to make a little force-pump, which he believed was the first time forced lubrication was used in any practical way. Ferranti's employer, Lord Wantage, had asked him

(Mr. William H. Allen.)

to put 3,000 H.P. into a cellar in New Bond Street, London. There were about fifteen engines in the cellar, and everything worked well except the outside bearing of an alternator. No doubt the bearing was too small, or it was not round, or set up, and it caused trouble, and Ferranti proposed a forced lubricating arrangement which acted perfectly. As an instance of how blind fashion was, after that time the outside bearing of nearly every alternator in the kingdom was made with forced lubrication, but to no other bearing was it applied. But why should it be limited to the outside bearing? Messrs. Bellis then took the system up, and adopted it for their connecting-rods; but why should it be limited to connecting-rods? In the end it went all through the engine, and since that day all sorts of machinery had been fitted with forced lubrication.

The advantages of forced lubrication were manifest. First of all, the machinery could be run very much faster; practically no oil was wasted because it was filtered regularly; and there was hardly any wear. As an evidence of that, he had in his Works a marvellous crank-shaft which had travelled 340 million revolutions. It was 6 inches in diameter, and was put into an engine made by his firm for Messrs. Harland and Wolff, and it worked for seven years. The engine had to be remodelled, and he thought it worth while to examine the crank-shaft; and, so far as could be measured by the micrometer, there was absolutely no wear on the shaft. No doubt that was the case with every other class of machinery which was working under forced lubrication. He trusted the system would be applied to every class of bearing, and not limited to one alone.

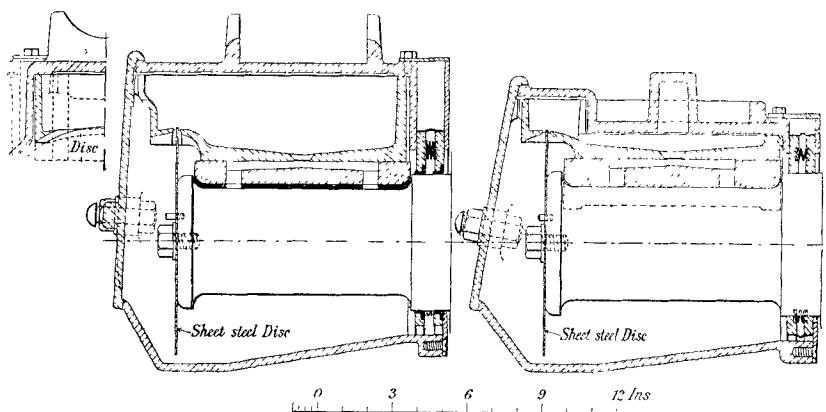
Mr. J. J. PODESTA thought it would add to the interest of the meeting if he showed the members something which was being done at the Patent Axle-box and Foundry Co.'s Works, not exactly in regard to forced lubrication, but at any rate with the same object in view, namely, of thoroughly and efficiently lubricating working axles. To illustrate the point, he desired to show two drawings giving particulars of the arrangements adopted. Fig. 4 showed the application to an ordinary wagon-box. On the end of the journal,

which was 9 inches by $4\frac{1}{2}$ inches, there was a disc of sheet steel about 9 inches diameter and about 16 S.W. gauge, which was secured by a bolt through the middle, a small dowell preventing any slip. The bottom of the box was filled up nearly to the level of the outside shield opening. There was a shield pressed from underneath, close up against the axle, and also pressed endways to prevent any oil escaping. A few days ago he put his finger to the back of a box which had run with that arrangement, and it was quite dry. People who had had experience knew that the bosses of the wheels generally got splashed

Tracier Axle-box (Wood and Carson).

FIG. 4.—As applied to English Standard 10-ton wagons.

FIG. 5.—As applied to 35-ton Bogie Trucks.



with oil, but in this case there was no trace of oil lost. The disc was all the time dipping in the oil bath, and every revolution it picked up a quantity of oil and carried it up to the key-plate, which was slotted for the purpose. The oil was taken off by both sides of the slot, and was guided by suitable channels cut in the sides of the key-plate, and brought down through a hole in the centre into the bearing.

The bearing he exhibited had been in use about four months; it had only run between 1,000 and 2,000 miles as yet, but it would be noticed that the traverse marks of the boring had not been worn out

(Mr. J. J. Podesta.)

at all, which showed the efficient nature of the lubrication. There were one or two scratches shown, but they were due to the roughness of the journal running in it. He also exhibited an old bearing which had been under the same truck, but with the old system of lubrication, and had been replaced by the new one, in order to show the rough nature of the work it had to do. The bearing which had replaced the former one was made with a white-metal facing, softer than the previous one, but it would be noticed how the hard material had suffered under the usual system of lubrication, while the softer was standing the strain well with the new arrangement adopted. The box had a very deep key-plate, but that was to accommodate the height of the spring seat; it could easily be arranged for lower spring seats.

The second drawing, Fig. 5 (page 605), showed a case in which the spring seat was lower, and the slot could still be obtained in front of the box. It was right out of the way, and did not interfere with any work at all. There was a continuous flood of oil. It might be asked whether the disc would pick up the oil when going at slow speed. Experiments showed that oil was well lifted, even when the truck was being shunted by hand in the yard. At eight miles an hour there was a regular reservoir of oil $\frac{3}{8}$ inch deep on the top, while at higher speeds there was no question of its reliability. A few days ago a wagon came in which had run from Wolverhampton to Hull and back again, and on examination it was found that hardly any oil at all had been lost.

Mr. WILLIAM SISSON thought the members would agree that the Paper described an interesting development in forced lubrication. He did not know what their experience had been, but his idea of forced lubrication had always been its application to those cases where there was an alternation of pressure, where the pressure was periodically applied and relieved. The development the authors had described showed that, at least in rolling stock, it was advantageous to apply forced lubrication to a bearing where the pressure was not entirely relieved periodically, as in the case of a crank-pin of a double-acting engine. He had been wondering whether the same

desirable result would be obtained, were it not for the vibration of the axle and the box on the permanent way and the end play, both of which were present in such a bearing as had been described. He wished to ask whether the authors had any results of the application of forced lubrication where the load was not relieved at all, and the oil pressure was not equal to the pressure per square inch between the surfaces.

He spoke with considerable diffidence in regard to what Mr. Allen had said, but he could not help thinking that Mr. Allen must have forgotten, when he stated that forced lubrication began in 1881, that long before that time, footsteps of vertical shafts were lubricated, not by the present system of forced lubrication, or as he thought it should be more properly called assisted lubrication, but by an actual oil pressure which was sufficient to lift the shaft. That was a different thing, the oil being actually forced in, and it might fairly be called forced lubrication.

He had adopted a connection with a flexible pipe in a plan he was now carrying out, not exactly for the same purpose, but for a similar purpose, where he wished to make a very high pressure connection, about 700 or 800 lbs. per square inch on to a part moving at the rate of about 600 strokes a minute, although the motion was small, and therefore he was glad to have the President's confirmation that he was on the right track in using a copper pipe with a good many bends in it. With respect to the belt-drive for the pumps, and the fact that different pressures were obtained when running forward and back, he supposed that must be due to the sag of the belt. The tight part of the belt was on the lower side when running in one direction, but on the upper side in the other direction, so that there was then more belt slip.

He wished to raise the question as to whether it was right to attempt to put the oil in at the top of the brass. Most engineers had been educated, by the classical experiments that Beauchamp Tower made years ago, into the idea that they must not put it in at the point of maximum pressure. If the system were used where the bearing was not in vibration and had not any end play, would there be a successful result? He asked, with respect, why not make two

(Mr. William Sisson.)

oil ways, one on each side of the crown? There were two oil-pump connections. That oil way which was on the leading side of the bearing could be fed by the pump which was in gear, so that the oil should be fed upwards on to the crown of the bearing, whichever way the vehicle was running.

He would never forget a diagram which the late Mr. Beauchamp Tower showed. He tried to oil his experimental brass at the centre, and he could not oil it; it seized. He gave that up and put a wood plug in, which was blown out. He then put on a pressure-gauge, and it showed about 700 lbs. to the square inch; the nominal pressure on the bearing was about 500 lbs. per square inch, so that the maximum pressure was thus about 200 lbs. above the mean. Most of them had got fixed in their heads the idea that they must not put oil into the crown of the bearing, and he submitted whether these two oil ways would not be an improvement. There were two pumps and two oil connections; why not give the crown of the bearing, where the maximum pressure was, the best chance?

He was exceedingly interested in the Paper, because it opened up a new development of the forced or assisted lubrication system, with which the names of Messrs. Allen and Messrs. Belliss and Morcom were associated. Splash lubrication had been a good servant. The Willans engine was a great success, and was bound to be a splash lubrication engine because it was a single-acting engine. With care good results could be obtained, but there was no doubt that forced or assisted lubrication gave facility in running at speeds and pressures that could not be attained so safely otherwise. Another advantage was the continuous filtering of the oil.

Mr. EWART C. AMOS said that he read with very close attention the valuable Paper for which the President and Mr. Bertie Reynolds were responsible. The subject was to him of more than ordinary interest, as he had been studying for some time past the question of forced lubrication as applied to rolling stock. He, for one, was therefore able to assure the President that the hope expressed by the authors in the concluding paragraph of the Paper, namely, that it would be useful to those investigating the subject, was amply

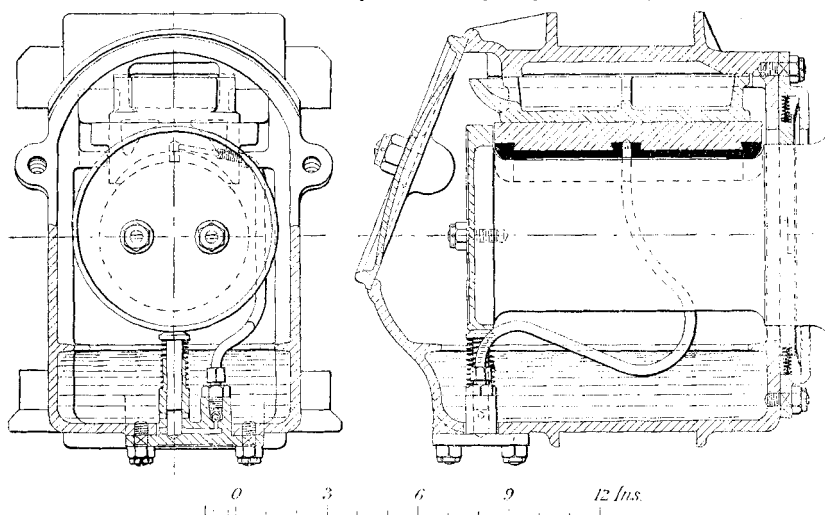
justified. Judging from the discussion, there could be no doubt that a great many engineers were now considering the matter very closely. In view of the wide and long experience which the President possessed in respect to railway matters, it was not his intention to offer any criticisms on the Paper; indeed he wished to thank the authors for the valuable information they had given. Mr. Tannett-Walker had remarked that there was nothing new under the sun, and that this was particularly true in respect to engineering, but he thought he was right in saying that the question of forced lubrication as applied to railway axles was of modern conception. His own investigations had led him to one conclusion on which he believed he was on sure ground, namely, that sufficient attention had not yet been paid to the question of lubricating railway carriage and locomotive bearings, and further that the solution of the question was only to be found in some system of forced lubrication. It seemed strange that members of the Institution should tolerate such a statement at the present date, or that their President should be introducing for the first time the question of forced lubrication as applied to locomotive bearings. He therefore very heartily thanked the authors of the Paper for laying before the members a method of achieving that very desirable object.

He had no doubt that more experienced members than himself would deal in detail with the Paper, but he might perhaps be permitted to refer to a few points. In the first place, the authors said that ordinary methods of lubrication unduly wasted oil and produced hot bearings. They then went on to describe the means they adopted for avoiding these troubles, and showed the difficulties which had to be contended with and how they were overcome. In conclusion they stated that theirs was one method of dealing with the subject. In view of that statement he asked the kind attention of the members, with the President's permission, to another way of effecting the same object. It was called the "Tilston" system of forced lubrication, and had recently been taken up by Messrs. Vickers, Sons and Maxim. So far its application had been confined to ordinary bearings, and with marked success, although he believed the Great Western Railway had adopted it in connection with some

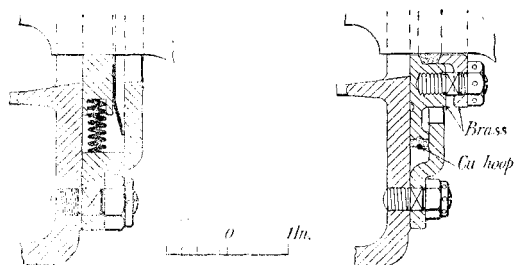
(Mr. Ewart C. Amos.)

of their rolling stock at Fishguard. At the present moment experiments were being made with railway bearings, and he exhibited some drawings illustrating the application of the Tilston system to

FIG. 6.—*Forced Lubrication System (Tilston) applied by Messrs. Vickers, Sons and Maxim to Cast-Steel Axle-box for 42-ton Bogie high-sided Wagon.*



Alternative Designs for Packing Ring.



standard axle-boxes, one of which was reproduced in Fig. 6. He also exhibited a working model of the system as applied to an ordinary bearing. Briefly described, the mechanism consisted mainly of an eccentric disc which was securely attached to the end of the

axle, and as that revolved it actuated a small plunger, which forced the oil through suitable passages to the point of greatest pressure. The question as to where the lubricant should be introduced was one on which he expected a good deal of discussion. In his opinion the point of greatest pressure was the only point at which lubrication should be applied. In the Tilston system no belting was employed, and each bearing had its own pump, which he thought was the best method. In these respects the system differed from that described by the President.

The advantage to be derived from a forced system of lubrication was that much less bearing surface could be used than was possible with ordinary lubrication, as there was practically no wear. Every locomotive engineer would say that that was ridiculous—and he was quite right, unless a particular object which everyone was seeking just now was achieved, namely, to get rid of the dust. The method of lubrication which he had described and illustrated claimed to be able to do this. In this country a good deal was known about dust, but in the Argentine, India, and other countries the nuisance was far greater. If dust could be kept out of a locomotive or railway-carriage bearing, forced lubrication was a simple matter. Until the dust was kept out, he questioned very much whether forced lubrication would obtain the success it was entitled to, because it was being run under unfair conditions. He believed Messrs. Vickers' difficulties had been chiefly in finding a proper method of keeping out the dust. Then again it must be remembered that in forcing the lubricant there was a greater opportunity for it to get out of the bearing than existed under the ordinary system. The Paper, however, had brought to the notice of the engineers of this country and of the Institution that the time had arrived when some method of forced lubrication should be applied to rolling stock generally, including locomotives.

Mr. MARK ROBINSON, Member of Council, desired to thank the authors for their careful and detailed description of a special application which was in itself a most interesting and valuable one; indeed he must echo the surprise the last speaker had expressed that

(Mr. Mark Robinson.)

it should be possible to describe this Paper as the first which had been published upon the application of forced lubrication to railway stock. His main object in rising to speak, however, was to call attention to the great general interest of the Paper, and to remind the younger engineers that during their time they might have to carry forced lubrication into most things that required lubricating. There was an increasing tendency to run most rotating things at higher speeds, too high for the old-fashioned lubrication; and where the difficulty could not be got round by ball or roller bearings, forced lubrication was necessary. He could not go back quite so far as Mr. Allen did in the history of the subject, but it was interesting to point out that not long after the time he mentioned, 1881, the double-acting engine found itself practically barred from high-speed work, which was then becoming of supreme importance, by the impossibility of lubricating the bearings satisfactorily by ordinary methods; the single-acting, or rather the "constant thrust" engine, with splash lubrication, had things all its own way. But in a few years forced lubrication, applied to the bearings of the double-acting engine, restored the balance, and the two types were again on a footing of equality, so far as good running was concerned. Thus nothing less than a revolution in an important branch of steam-engine construction was worked by forced lubrication, and it might be destined to do as much for other branches of engineering.

Mr. Sisson had referred (page 606) to the use of forced lubrication in bearings where there was not a variation in the direction of stress, and asked if it was suitable in such cases. The answer was that the steam-turbine (with the possible exception of very slow-running marine turbines) could not be used without forced lubrication; they absolutely relied upon it. Yet in turbines the weight of the rotor and shaft was constantly on the lower brass, never relieved by alternation of stress in even the smallest degree; not even by such vibration as, probably, helped the lubrication of the axles of rolling stock. As both Mr. Sisson and Mr. Amos indicated, in the satisfactory working of forced lubrication, a great deal depended upon the position of the oil channels in the brasses, and upon the particular place at which the oil was taken in. The laws governing these points were not always as obvious as they seemed to be.

Mr. DANIEL ADAMSON thought it would have been better for those members who were not railway engineers, if the authors had reminded them that the point of maximum pressure referred to by Mr. Sisson was not actually at the top of the bearing but a little to one side. These being driving axles the point of maximum pressure would fall alternately on the forward side of the top centre and on the rear side (depending upon the direction of motion of the piston) giving the alternate action referred to by Mr. Sisson. He reasoned it out that, under those conditions, the position of maximum pressure would be a certain amount to the front of the centre of the top during the time the piston was moving in the same direction as the locomotive, and on the return stroke a smaller distance behind the centre. If this reasoning were correct, then reference to the diagram given by Beauchamp Tower* would show that the actual pressure at the point chosen by the authors for the application of the lubricant would be less than the maximum pressure, and would also vary according to the direction of motion of the piston of the engine. The effect of this variation would be to allow easier access for the oil during the alternate strokes of the engine, and might explain the variation in the slip of the belt referred to by the authors. Perhaps the authors would in reply express an opinion as to whether this suggestion or the one by Mr. Sisson was the more likely to be correct.

He wished to express his agreement with Mr. Sisson in his criticism of the position chosen by the authors for the application of the oil, and he did so with more confidence because a Paper upon Assisted Lubrication of Axle-boxes (it had already been said by previous speakers that the method described in the Paper was "assisted" lubrication rather than "forced" lubrication) was written by an eminent railway engineer, Mr. W. Bridges Adams, more than fifty years ago† describing a system in which the oil was applied on the *lower* side of the bearing, in that case by rollers, as against pumps in the present instance. This seemed to confirm his own

* Proceedings 1885, page 61.

† Proceedings 1853, page 57.

(Mr. Daniel Adamson.)

opinion that it would be better to apply the oil (at the low pressure chosen by the authors) at some other point than at the upper portion of the bearing.

Mr. JOHN A. F. ASPINALL, Vice-President, inquired whether part of the idea, and perhaps the leading idea, in dealing with the question of forced lubrication had not been to have a rather better mechanical distribution of the lubricant than forcing it between two surfaces. With rolling stock there was not the same difficulty in getting a lubricant to flow easily that was experienced with engines of a stationary character, because the intense vibration to which the rolling stock was subjected served in some way or other to open out the surfaces, and to induce the lubricant to flow in a way it could not be made to do in other kinds of machinery. He assumed that possibly there might have been another idea, namely, a certain amount of oil economy. The present systems of lubrication for rolling stock, though perhaps looked upon as crude, were certainly very efficient when one considered that a locomotive starting, say, from Paddington and going for a long run to the West of England, or from Euston right away to Liverpool without a stop, had nothing whatever done to it during the journey. The driver had to look after his signals; the fireman had to look after his coal; the engine must look after itself. The only time that could be given to the engine was before it started and after it arrived; and the mechanism of lubrication must be of such a perfect character that it required no inspection whatever during the journey. If mechanical lubrication was to be introduced instead of the simpler methods of the past, it must be of such a character that it would require no looking after whatever.

One of the difficulties of lubrication upon a railway was that of the dust which in the summer was of such a serious character; and not only on account of the dust but of those very fine ashes which came out of the smoke-box, and which were familiarly known by locomotive men as "chimney end." There was no aperture so small that they could not enter; there was no cavity so great that they would not fill in time. The form of axle-box that was used in

a locomotive, which had naturally to be open at both sides because it had a crank-web on the one side and the wheel-boss on the other, was perhaps a little more difficult to look after than the forms of axle-box shown in the diagram exhibited, Fig. 6 (page 610), which were the forms generally used for wagons or carriages, but which had the advantage of being closed at one end. That form meant that a dust-guard could be used, and so long as it was a good fit, it prevented a great deal of the dirt from entering between the surfaces.

He noticed in one case on the diagram that apparently the lubricant was being transmitted from the central reservoir to the bottom of the journal. Although the President's diagram, Plate 17, showed the lubrication to be forced between the surfaces at the top of the journal, he would have thought it would be better to adhere to that form of lubrication which had been found so good in all axle-boxes of that class—lubricating from the bottom rather than attempting to force the lubricant in from the top. In the method which was apparently shown in the diagram he assumed that the oil was forced in a kind of jet which spread itself over the surfaces as the axle rotated. Whether the authors had tried that in any larger vehicle than the rail motor-cars he did not know, but if so, he would be glad to have information.

Mr. ALFRED SAXON congratulated the President and his colleague on introducing the subject of the Paper, because their system of lubrication applied in many directions other than the one dealt with in the Paper. He had been particularly struck by the fact that the President's system, practically on his own admission in the Paper, was not strictly reliable. A mechanical chain-drive would, he thought, suit the system the authors had described and be more reliable.

With regard to the question of lubricating where the thrust or pressure was, he thought Mr. Sisson had touched the spot in the remarks he had made. Where for a time a bearing was under tension or thrust, so far as the pump pressures described were concerned, he did not think they were sufficiently high to give

(Mr. Alfred Saxon.)

much relief, but the flushing of the bearing was probably the best thing which could happen as an alternative to relieving the bearing of pressure.

A Paper was contributed some time ago to the Manchester Association of Engineers by Dr. J. T. Nicolson on Friction and Lubrication,* and the author there described the Tilston bearing to which Mr. Amos had referred (page 610). That, undoubtedly, was a good bearing; he had not a word to say against it in that respect. A claim was made, however, by Dr. Nicolson that if engineers and millwrights were to adopt that style of bearing they could reduce their standard length of bearings one-half or one-third. There were some drives in mill rope-races where a pull somewhat equivalent to the thrust in railway axles took place. He stated at the time that he was willing to have two of those bearings put to a practical test, of the dimensions that Dr. Nicolson thought would serve the purpose, but he (the speaker) had not heard anything about it since.

It ought to be remembered that standard practice had been adopted based upon actual working experience, and it was very unsafe for people to make the claims they did with regard to reduction of sizes and costs without going fully into the question. A fixed plate for lubrication had been described by one of the speakers. In general practice loose oiling rings were extensively used, and that was a very effective system of lubricating the rope-race bearings he had referred to, being much simpler and more reliable than pump lubrication. He believed the Tilston pump was about as simple a pump as could possibly be arranged, and if it proved to be really durable then they would have a good system of flushing the bearing, and probably relieving the friction to a slight extent.

Mr. F. G. WRIGHT thought that there were cases where forced lubrication was of great advantage, and he had no doubt there were others where they were able to lubricate satisfactorily without using it. On the Great Western Railway they had the longest run in the

* Transactions, 23 November 1907, page 65.

world, running from Paddington to Plymouth in both directions, sometimes two or three times a day without a stop, and during last summer they never had a single hot axle. He considered that was an excellent performance, taking into account the millions of miles that the rolling stock ran, and the same remark applied to the wagon stock fitted with oil axle-boxes.

The Great Western Railway Co. made use of a system which could be explained by calling it "lubrication by centrifugal force." An axle-box was used in which a pad was inserted, and no holes were allowed through the bearings at all. When the axle was in motion there was a film of oil between it and the bearing. Even after it had run thousands of miles the scraper marks could be seen on the bearing, and where case-hardened axles were being used the grinding marks could be seen on them. He did not think there was any opening for forced lubrication on rolling stock. To his mind the great necessity for mechanical engineers was to work out problems in the simplest possible manner, and to avoid complications which were unnecessary. The rolling stock on the Great Western Railway was 70 feet long, with four-wheeled bogies, and if forced lubrication were introduced many complications would have to be dealt with. He would like to know what would happen if the pump failed, or if the pipe broke.

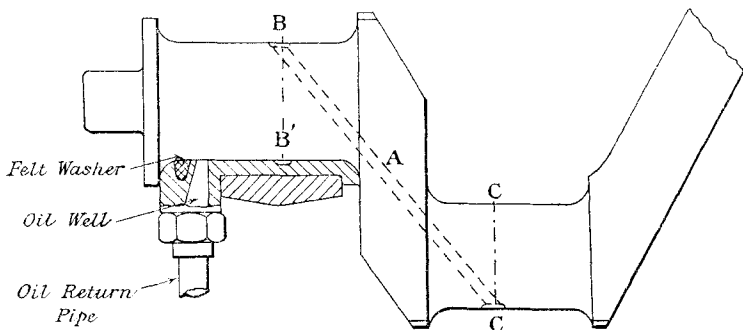
As the driver of a motor-car, there were many things he would like to do away with. If the tyre were punctured, or if the fan-belt came off, one was bound to stop. Personally he had no pump for his circulating water—it was done by thermo-syphon; and he had no forced lubrication, which was totally unnecessary in his opinion, except in very large motor-cars, because it was possible to lubricate quite well by gravitation. In that way he reduced the working parts to a minimum, which to his mind was the essence of successful rolling stock—to have an axle-box of the simplest possible construction.

Mr. L. A. LEGROS said he did not quite agree with Mr. Wright's remarks about motor-cars, as he thought it was advisable to fit forced lubrication to the engine. That was done in a manner very

(Mr. L. A. Legros.)

similar to that which Mr. Allen and Mr. Mark Robinson had already described. In the axle-box the authors had designed he noticed they had avoided one great risk there was in adopting forced lubrication for the axles of rolling stock, namely, drilled holes in the axle. The authors applied their lubrication through the brass. Personally he thought it was much more difficult to ensure proper lubrication by that means than by applying it along the shaft. If holes were drilled in the axle, fracture was liable to originate at the centre of the drilled holes. He had noticed that had frequently happened on tramways. Some tramway axles which he fitted himself had a set-screw for retaining a chain-pulley, and the axles started to crack

FIG. 7.—*Motor Crank-shaft with forced lubrication.*



through those pointed drilled holes, in the way which all engineers were familiar with in fatigue experiments. That cracking could be avoided by putting a very big radius at the outside of the drilled hole, a point to which great attention ought to be paid in making motor-car shafts with forced lubrication for the connecting-rods and gudgeon-pins. It was necessary that the holes which carried the lubricant should be very well rounded out, if one wished to have no fracture.

The hole was drilled through the bearing as shown at A, Fig. 7. It was necessary that the holes should be very well rounded out at B and C, so as to avoid the fracture starting at B or C and cracking the shaft through BB' or CC'. In fitting these bearings it

had been found that an oil-pressure of only 2 lbs. per square inch was sufficient for a motor-engine running from 1,400 up to 2,000 revolutions a minute for a journal 2 inches diameter and a crank-pin $1\frac{3}{4}$ inches diameter. It had also been found that it was possible to sacrifice as much length of bearing on the journal as was necessary for the felt guard for keeping the dust out.

Mr. EWART C. AMOS desired to make two remarks in reply to the discussion which had since occurred. It seemed to him that the channel described by Mr. Legros was more likely to produce fracture than the small set-screw adopted for attaching the disc in the Tilston system. It was not a *sine quâ non* that it should be attached in that way. In the second place, the Tilston system permitted of the ordinary system being retained, if desired.

Mr. NOEL CHANDLER said he had recently had some experience with axle-boxes, which were lubricated from the bottom by some soft wool waste which was pushed in, and they had given complete satisfaction. The capillary attraction had the effect of taking the oil up to the bearings from the oil basin, and the axle-boxes had run completely free from wear for three months on some colliery wagons. He had also had experience with some high-speed engine-bearings, and he found that if oil were forced into an annular space cut in the centre it was quite sufficient to lubricate the bearing the whole way along. That did not weaken the bearing at the point where the greatest pressure occurred, namely, at the top and at the bottom in a double-acting vertical engine. The oil seemed to spread from the central groove, and no other provision was necessary.

Mr. HENRY DAVEY, Member of Council, thought that if the old Watt engine had been adhered to forced lubrication would not have been required. The whole question seemed to him to turn on the conditions of working. Mr. Allen would no doubt agree with him that the modern high-speed double-acting reciprocating engine would not have been possible, had it not been for forced lubrication. He thought forced lubrication was not a question of general, but of

(Mr. Henry Davey.)

special, application. There were bearings which could be properly lubricated without it.

The PRESIDENT, before calling upon Mr. Reynolds to reply, said that Mr. Allen wanted to know what the system of lubrication described in the Paper cost so far as the oil was concerned. As Mr. Reynolds would state in his reply a great many experiments had been carried out, and an improvement in the working had steadily been made. The cars were now run 180 miles with only two pints of oil, a result a great deal better than had previously been accomplished. Experiments were still being carried on, and, if possible, he would supply up-to-date details of them. Mr. Wright and Mr. Aspinall had very naturally asked why the system of lubrication which had been described should be used at all. He agreed with them that where it could be dispensed with, he would not think of using it; he would not put such a complicated arrangement in where he could get engines to run perfectly freely and well, as they could with plenty of surface and proper conveniences for being able to sustain lubrication during the running of the train. But where there were heavy weights and exceptional conditions, such as where cars had to run hammering away at thirty miles and very often forty-five miles an hour, with very small wheels, with a high speed of journal, very confined in space, and where everything had been cut down to the lowest possible dimensions, it was not possible to adopt a proper and satisfactory system of lubrication in the ordinary way, and it was for that reason that the little device described in the Paper was made.

It was a great pleasure to Mr. Reynolds and himself that the members had taken such an interest in discussing the subject. Mr. Adamson and Mr. Sisson had found fault with lubricating the crown of the brass. What Mr. Adamson said was perfectly right, namely, that the maximum centre of pressure was not immediately over the centre of the journal when running in either one direction or the other, and therefore they did accomplish, although not perhaps in the very best way, what was desired, that is, to feed the supply of

lubricant immediately in front of that pressure. In that way the consumption of oil had been enormously decreased, and he believed it was capable of very material further improvement.

With regard to lubricating from the haunches of the bearing, that was all right if the bearing did not wear; but those who had experience of bearings where the pressure was above knew that it did not take long for the hips of the bearing to be jammed much faster than the crown. The crown wore quicker; the hips got tighter; and, unless the entire journal was lubricated, it would be found that the hips would very soon generate sufficient heat to give trouble. That was why the lubrication had been tried. He had a large number of journals running with lubrication in the hips, but not under those exceptional circumstances. He had tried that method and found it a failure. He therefore devised another way, and was successful by the use of the method described.

Mr. BERTIE REYNOLDS, in reply, said that many of the speakers seemed to think that a rather complicated system had been adopted for a very simple problem. He did not think that was the case. Although there were many forced-lubrication systems in existence, he did not think there was one which applied to such a problem as that connected with the steam-cars on the Taff Vale Railway Company. Some of the systems were suitable for other bearings which could be easily got at, and which could be boxed in and the dust kept out. There were also systems that would deal with wagon bearings so far as forced lubrication was concerned, but nothing that the authors knew of which would deal with the bearings of an engine or a steam-car. They had to deal with their own problem, to start with their own data, and devise a system to prevent the cars from running hot and using an excessive amount of oil, which they used to do. That was why a rather more complicated system had been built up; but one of the objects of the Paper was to discover what other people knew on the subject, to get from them that information, and see whether it could be adapted for their own purpose on the Taff Vale Railway.

(Mr. Bertie Reynolds.)

A question had been raised with regard to the point of maximum pressure on the bearings. Some members had said that oil should be put in at the sides, and others said it should be put in at the top. Personally he believed the oil should be put in at the top of the bearing. Engines were running on the Taff Vale with both systems, and the bearings with oil at the top ran very much better than those which took it in at the sides. Mr. Adamson pointed out that there was a fluctuation in the point of maximum pressure due to the engine running forwards or backwards, and that must be taken into account.

One of the speakers had raised the question that a chain-drive might easily have been adopted instead of the belt-drive, which was likely to give way at any time and give trouble. The chain-drive, however, did not allow for the relative motion of the driving axle and the pump, which motion had to be taken into account, otherwise trouble would ensue. A belt had therefore been put in which served its purpose; it slipped a little, but that was allowed for. The revolutions of the pump were 400 to 500, allowing ample margin for any slip.

The question had been raised as to whether there was enough oil-pressure to really relieve the pressure on the axle-box. They did not want to do that exactly; all they wanted to do was to get the cars to run with cool bearings, and to save oil. It was found in practice that a pressure of 20 lbs. of oil per square inch was quite enough. A journal was rigged up in the shops, and the pressure was run up to 80 lbs. per square inch, but it did not have the weight on it that obtained when under the steam-car. The experiments were still being continued, and any further results would be sent up for publication in the Proceedings.

Mention had been made of the difficulty of keeping out the dust. The authors found not so much difficulty in keeping out the dust, as in keeping out the water. As soon as the water got in, in any considerable quantity, it was found that the system was affected. That difficulty had now been overcome, and no water got in. The system had not been tried on locomotives. The present

experiments were being carried out on steam-cars, and as soon as those experiments were finished he had no doubt the President would be progressive enough to try them on an engine, and obtain further information.

Communications.

Mr. J. G. H. WARREN wrote that it appeared that forced lubrication had been introduced as a corrective in a motor-carriage, which had to meet exceptionally high speeds with small journals, the reasons for adopting which were not given in the Paper. He wished to point out the undesirability of spending money generally on assisted lubrication, on the ground only that the system had been found useful in overcoming the heating of an overloaded axle. The difficulty would not have arisen with a suitably proportioned journal.

The AUTHORS wrote, in continuation of their remarks at the Meeting, that the system of forced lubrication—or assisted lubrication, as many preferred to call it—had answered satisfactorily since the writing of the Paper. Further cars were being fitted as they came into the shops, little alteration being made in the details shown in the published drawings. It was found, however, that as the bearings wore, and the play between the axle and axle-box increased, the oil, being under pressure, escaped at the sides of the boxes and was splashed around the wheel-boss, giving a much greater consumption of oil than that stated in the Paper. To prevent this, a narrow groove had been cut round the sides of the bearing of each box for a depth of $\frac{3}{8}$ inch at the crown, and tapering down to nothing at the hips. The neighbouring oil then lost most of its pressure at this groove, and flowed back to the keep to be collected, instead of being forced out round the boss of the wheel. The leading idea in

(The Authors.)

the adoption of the arrangement, in the first instance, being economy in oil, it would be observed that any device for preventing the escape of oil was important. Other small alterations had been carried out, but, in the main, the arrangement stood as described.

The opinion expressed in Mr. Warren's communication, that a single successful application of assisted lubrication was not sufficient reason for spending money on it, was not likely to appeal to an engineer who appreciated the advantages gained. As to the proportions of the railway motor-car, these were not dealt with in the Paper, but, since Mr. Warren had brought up this subject in reference to the axle, he wished to point out that in a railway motor-car of this kind it was not possible to use an axle of larger journal bearing surface; and therefore only one alternative to assisted lubrication remained, namely, to put another pair of wheels on to the car, and thus make the whole vehicle heavier and less efficient for the money spent upon it.

Fig. 2. OIL-TANK AND PUMP FOR STEAM-CAR ON TAFF VALE RY

Plate 16.

AXLE-BOX FORCED LUBRICATION.

Plate 16.

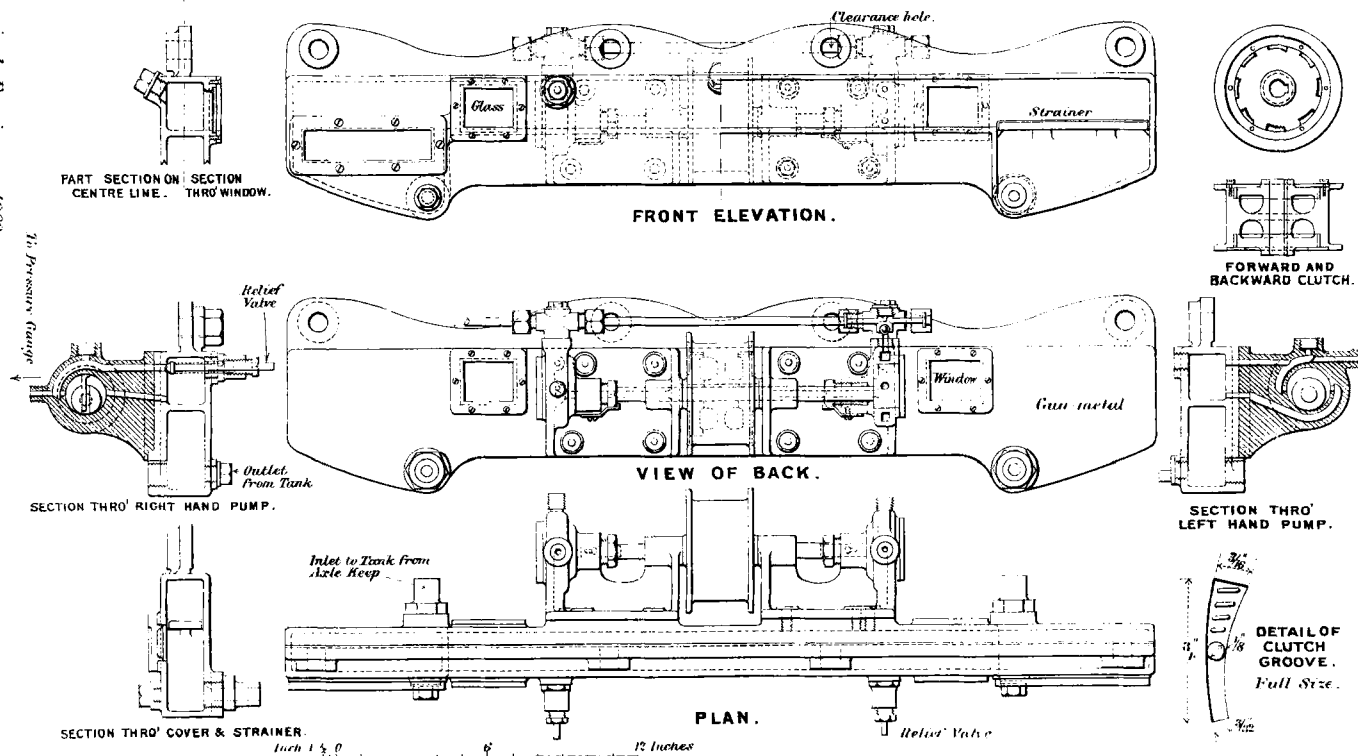


Fig. 3. DRIVING AXLE-BOX AND KEEP FOR STEAM-CAR ON TAFF VALE RY

