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G.W.R. Mechanics' Institution, Swindon.

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Chairman—Mr. G. H. Burrows Assoc.M.I.Mech.E.

" THE PRACTICAL WORKING OF A LOCOMOTIVE,"

BY

R. H. SMITH, (Member).

With Discussion.

The Author's object is to give a fuller and clearer insight into the routine devolving upon the men engaged in working the Locomotive, which has become a mechanical achievement of the highest order.

Before dealing with the subject proper, it would interest many to know something of the methods adopted by the Great Western Railway Company in the selection and training of men who are employed on the practical working of a Locomotive.

Selection of Men.—It is perfectly safe to say that fully ninety per cent. of locomotive drivers commenced their railway career as engine cleaners. Promotion to first grade of firemen is followed strictly on the principle of seniority, but each man must fulfil the following qualifications :—

1. Must bear a good character, and be recommended by Foreman and Superintendent respectively.
2. Must be over 18 and under 21 years of age.
3. A servant of the Company not less than four months.
4. Able to read and write distinctly.
5. Must be 5 feet 4½ inches or over in height, and weight in proportion ; not less than 34 inches round chest ; have sound teeth.
6. Able to pass an exceptionally strict eyesight test and medical examination.

Eyesight Test.—The eyesight test consists of discrimination of colours, in addition to form vision, and is so severe that men only with perfect eyesight are able to pass it. The sight is tested at least once every five years. The medical test is also above reproach, and candidates are not accepted whose parents have died from any hereditary disease, or if mental affliction has appeared in the family.

Illness Record.—The illness of each man is recorded after appointment, and if repeatedly absent from duty an additional medical examination is made by a specialist.

Intellectual Requirements.—With regard to intellectual requirements, these are not tested at the initial stage of a fireman's career ; in fact, it is not until after a man has worked many years on the footplate, and becomes a candidate for the first class, or in other words, passenger grade of fireman, that the question of his mental abilities arise. This, the Author's experience has taught him, is one defect in the system, which will be dealt with in due course.

Training Of Men.—Cleaners are not confined to engine cleaning exclusively, but are called upon, occasionally, to light up engines, raise steam, wash out boilers, act as fitter's mate, and other similar engine shed work, so that, before being appointed firemen, some knowledge is acquired of the various parts of the Locomotive and their uses.

A still more systematic and scientific training for firemen is desirable. Most men, when appointed firemen, have no knowledge of the injector and its application ; do not understand the elementary principles of combustion, generation and application of steam, the expansion and contraction of the boiler generally, how water is economised in working the regulator and reversing lever, how a fire requires to be made compatible with certain conditions, measures to be taken in case of breakdown to engines, etc.

If such knowledge were insisted upon, the saving to the Company would be enormous. Take, for example, the principles of combustion. Firemen deal with coal to the value of £600,000 annually, and it is estimated that a fireman deals with £10,000 worth during his career. How can he be expected to extract its fullest value without the slightest theoretical knowledge of its properties and combustion? Information gained by practical experience, as at present, must of necessity be a source of great expense to the Company. Considering also the facilities now afforded for technical instruction, there would be little difficulty in regard to a man studying the scientific side of Locomotive driving. If such methods were insisted upon, it would certainly be of great benefit, both to man and master, and thus ensure efficiency with economy.

Examination by Inspector.—This consists of an examination upon the Book of Rules and Regulations, and knowledge of an engine. The men also have to demonstrate that they are capable of acting judiciously and promptly in exceptional circumstances, such as the failure of an engine, or disorganised conditions of working. The examination is made at Swindon by a Locomotive Inspector, who has to give a written certificate of the result to the Chief Locomotive Superintendent. Further tests are held before men are promoted to the first and second grades of driver. There are about forty questions to be answered at each trial, and the percentage of rejections is very low indeed. Three tests are allowed, but the majority of candidates succeed at the first attempt, and a complete failure is a rarity. This is principally due to the fact that the men, realising the importance of the examination, hold preparatory classes at each of the large Locomotive centres, which are termed "mutual improvement classes." They are conducted by men who have made the art of engine driving a special study, and are competent instructors. Helpful text books, such as the "Catechism of the Locomotive," have also been compiled. These can be bought at a nominal figure, and are extremely useful.

As most of you are aware, the trains to be run and other conditions vary very considerably, and, consequently, enginemen and firemen are graded, and the work classified relative to each grade.

Duties of Firemen.—He must book on duty at the engine shed one hour prior to train starting time, except when otherwise arranged, and obtain the keys of the tool boxes, etc., from the timekeeper or person in charge. The latter is responsible for personally seeing each man. Punctuality is strictly enforced, and boys are employed to call men who have to book on duty between 12 o'clock midnight and 7 in the morning. On reaching the engine the fireman opens the tool boxes and sees that all requisite tools are handy, notes the steam pressure and water gauge, examines the fire, observes the condition of the tube plate and brick arch, tests the ashpan dampers to satisfy himself that they are in working order, examines the smokebox to ascertain that it is properly cleaned and door securely fastened, observes that the ashpan has received proper attention, and that the firebars are in their right position. Makes up the fire suitably for the work to be performed, taking care that the whole of the grate is covered with fire, especially near tube plate. Trims and fills head and gauge lamps, and repacks or tightens up glands as found necessary (the introduction of metallic packing is dispensing with the latter work). Fills tank or tender, finally makes up fire, well waters coal, sweeps and washes footplate.

An engine as a rule has to be attached to its train, 10 minutes in the case of a passenger and 15 for a goods train, before booked starting time, except where circumstances demand otherwise. It will be seen, therefore, that for a fireman to get through the whole of his work before starting on the journey he must be energetic as well as methodical.

Chief Duty of Firemen to Maintain Steam.—The chief business of firemen after joining the train is to maintain the steam pressure. They act under the supervision of the drivers, whose views vary as to the most effectual and economical method of accomplishing this, but the Author will deal with the subject more fully under the heading of "Fires."

Good Judgment Necessary.—Although firemen do not act entirely on their own initiative, this in no way affects the fact that good judgment is of the greatest importance. Sound judgment correctly measures all the conditions, and prompts correct action at the right time. Knowledge without judgment will blunder, whereas good judgment with less knowledge will succeed. Obedience, co-operation, willingness to learn, and profit by experience of enginemen are also most essential qualifications of firemen.

Fire When Starting.—When the engine joins the train there should be sufficient fire covering the grate to prevent pulling.

Steam Pressure.—The steam pressure should be 5 to 10 lbs. below "blowing off" point, and the boiler have as much water as it can carry without priming.

Working Injector.—After starting the fireman must bear in mind the character of the road over which the train has to run, and regulate the fire accordingly. Good judgment is also required in the use of the injector. The habits of the engineman in working the engine should be observed, and the changing conditions anticipated. Coal must not be added to the fire just before steam is going to be shut off, neither immediately after it is applied. The fire should be kept as light as possible consistent with the work. Heavy firing cools the firebox and causes contraction and expansion of boiler plates. The engine should not be allowed to make smoke, and the use of the blower should be avoided as much as possible.

Even Pressure Necessary.—When firing the constant aim should be to keep an even pressure. Boiler feeding is most important, for sudden change of pressure injures the boiler, and great care must also be exercised in effectually using the dampers.

Duties of a Driver.—The Author has given in detail the principal duties of a fireman, and will proceed with those of an engineman. He also books on duty at the engine shed one hour prior to the booked train starting time, and then receives any special notices or instructions with regard to his day's working from the timekeeper or person in charge. On reaching the engine he satisfies himself that his mate satisfactorily performs his duties in the best and most expeditious manner possible. He examines the safety plugs, tubes and stays, obtains the necessary oil, etc., from the stores, fills oil feeder, places engine so that the right big end is in bottom position. Obtains a $\frac{1}{2}''$ and $\frac{5}{8}''$ spanner from tool box, and goes underneath engine to oil working parts and examine all portions of the machinery, particularly bolts, nuts, pins, springs and such like. He then attends to the trimmings in big ends and eccentric straps, overhauls all pipes and connections between engine and tender, also water scoop. Coming from underneath back of tender he proceeds to oil, and inspects the tender and engine all round, commencing the left hand side. In the case of a coupled engine, before attending to the right side it is moved so as to bring the right outside rod on the back bottom angle. Returning to footplate, the lubricator is filled with oil and ejector tested. Methods should be adopted in carrying out these duties to ensure no part being overlooked, either in examination or lubrication, because if done in a slovenly manner they will surely tell their own tale when the engine is attached to the train.

Knowledge of Roads.—Enginemen most have a thorough knowledge of the roads over which they run, for this is essential for economical working and safety of life and property.

Starting of Trains.—In starting a train it is usual to have the brakes well off and lever in full gear. The regulator should be opened carefully to minimise the possibility of slipping, and to avoid a sudden snatch on the drawgear.

Reducing the Cut Off.—When the train has attained sufficient momentum the "cut off" should be reduced. If, however, after reducing to about 12 per cent. the speed of the train is still found to be in excess of schedule time, it should be further controlled by the regulator valve. A diversity of opinion exists as to the most economical method of working. Some consider it is best to work at a long "cut off" with a minimum of 20 per cent., and to manipulate the regulator valve accordingly. The Author is of opinion, however, that the best method is to take advantage of the full boiler pressure as far as possible. Having made many experiments in this direction, practical experience has taught him that the higher the initial pressure in the cylinders the more economically the engine is worked.

Speeds.—From long experience, drivers are able to judge the speed of their trains when running, and this is clearly shown by the way they work them to schedule time without any appliance to indicate the speed.

Stopping of Trains.—In stopping a train, great judgment has to be exercised, and the condition of the rails, gradient, load, speed and brake power available taken into account.

Examination of Engine after Completion of Journey.-When the destination of the train is reached, the engine is taken to the shed, and the driver there makes a thorough examination of it. This duty should be carried out in the same comprehensive manner as that made previous to leaving the shed before commencing the journey.

Reporting Defects or Repairs Required.—Any defects or repairs required to the engine must be reported by the driver, and entered in the book provided for the purpose before he books off duty.

Stabling Engine in Shed.—The driver is also responsible for seeing that when the engine is stabled in the shed the boiler is filled with water, regulator properly shut, reversing lever in mid-gear, cylinder drain cocks open, and hand brake hard on and secured by chain.

FIRES.—Fires may be enumerated under the following heads:—

(*a*) Flat.

(*b*) Side.

(*c*) Saucer.

(*d*) Four Corner.

(*e*) Centre or "Haycock."

It is impossible to lay down a hard and fast rule as to which of these fires is the best under all circumstances, as there are so many conditions which have a vital bearing on the result. The driver, in deciding the fire to be adopted for the day's work, has to take into consideration the quality of coal at his disposal, the type of engine and firebox, the load to be dealt with, and the class of train, *i.e*, slow or express goods, heavy mineral, stopping, or long distance non-stopping passenger trains. Experience and good judgment, to correctly measure all the conditions, are indispensable to combine efficiency with economy.

Flat Fire.—A flat fire is one which is level all over the grate, and about nine inches to one foot in depth. To maintain this fire demands very skilful and laborious work, as coal must be added constantly, and equally distributed over the whole surface of fire. With bituminous coal the combustion is rapid, but the amount of smoke which is emitted from chimney would prove that it is not so perfect as it is possible to get in a Locomotive firebox. With semi-anthracite fuel, however, this fire is the best obtainable with any class of engine or train.

Side Fire.—A side fire is made by thickening the depth of fire on the four sides of grate in proportion to the depth of firebox, leaving the centre very thin and open. Fuel is added to the front, sides, or back of fire, as required, the large coal naturally working to and feeding the centre. The combustion of bituminous coal with this fire is comparatively good when skilfully manipulated. A number of men favour the side fire, and in many instances the results have been excellent. This type of fire, however, is impossible with semi-anthracite or hard northern coal.

Saucer Fire.—This is a compromise between the flat and side fires, the chief difference being that the centre is thicker and the sides more open. It is a difficult fire to work, good for generating steam, but not economical.

Four-Corner Fire.—This is somewhat similar to the side fire ; the bulk of the fire is on the four corners of the grate, the centre being thin and open. The fuel is added directly in the four corners, the result being that, in addition to the middle, the front, back and sides are also practically thin and open. This type of fire is not a popular one as it is difficult to keep in order and is considered expensive. It can only be adopted with good bituminous coal.

Centre or "Haycock" Fire.—A centre or "Haycock" fire is made by having a body of fire on the centre of grate some three or four feet in thickness, in proportion to depth of firebox, the sides being shallow and open. Only bituminous coal can be utilised for this class of fire. The fuel is always added to the centre, the smaller coal remaining there, but the large lumps work to the sides. The combustion takes place principally at the latter points, and is not so rapid as with other types of fires. With bituminous coal of fairly good quality, and skilful handling, there can be no doubt that the centre fire is the most effective and economical possible. Ebbw Vale coal has earned a great reputation on the Great Western Railway for steam generating purposes. It should be explained, however, that this is not on account of any exceptional quality in its composition, but is entirely due to the fact that it is peculiarly adapted to the centre fire, which is a favourite one with the men, and the easiest to use in long fireboxes. It is the best, also, for the French pattern fireboxes, and is generally adopted in the G.W.R. Nos. 1, 2, 3 and 4 pattern firegrates. The raised centre or "Haycock" fire is carried from the firehole door to the slanting bars only. Owing to the large body of fire it is not so liable to be lifted or pulled out of shape when engine is working heavily.

Fuel Economy.—Excepting wages paid, fuel is the largest expense incurred by the Running Department, therefore should be used carefully. Safety of life and property, of course, is the primary consideration of enginemen, but the matter next in importance is economy with efficiency. A record is kept of the amount of coal and lubricating oil supplied to each engine, and monthly statements are prepared showing the consumption of coal per mile and oil per 100 miles run. These records are carefully scrutinized to detect extravagance. Drivers of the first and second class grades receive a bonus or premium of £5 each half year if they succeed in working their engines cheaper in fuel and oil than the average cost of the link in which they are classified. Some incentive, therefore, is given to a proportion of the men to be careful with the fuel. A copy of the fuel consumption statements is exhibited in the various engine sheds. Drivers generally take a good deal of interest in these monthly reports, the result being that a spirit of emulation is created, which has some effect on the coal consumption. It will be impossible to give details of all the various methods adopted by an engineman to save fuel. Success in this direction depends mainly upon whether he has fully profited by his experience and is able to work his engine and fire so as to obtain the maximum amount of heat with the minimum consumption of fuel, irrespective of the class of coal used. Another important point—the manipulation of the reversing lever and regulating valve to ensure that no power is expended beyond that which is absolutely necessary to work the train to schedule time—must also be borne in mind. A great waste of fuel occurs if the engine is allowed to blow off steam at the safety valve. When approaching terminal stations the fire should be run down to its lowest limits. Although the loads of trains and number of large engines have considerably increased, the average consumption of coal used per mile run has shewn a tendency to decrease, in fact, the average for the year ended June, 1905, was lower than either of the preceding five years. It is feared, however, that but little of this is attributable to the increased carefulness on the part of the drivers, but to the engines being maintained in better working order, superior quality of coal, and additional vigilance in supervision.

Lubricating Valves, Cylinders, and Working Parts.—Oiling is of paramount importance, and drivers have to devote considerable attention to the lubricating of the various working parts of the machinery. Instances of hot bearings, etc., from lack of lubrication are comparatively rare, which denotes that men carry out this portion of their duties thoroughly. Many men cultivate the most rigid economy with oil, but a number who are exceptionally careful in other respects use it somewhat extravagantly. This is not because they do not take sufficient interest in the matter, but it is entirely due to lack of confidence. A successful driver knows to a nicety how much oil to apply to the various bearings, whereas another is over anxious and uses more than is needed. The distinction to an inexperienced man, perhaps, would be considered very fine indeed, but a few extra drops per bearing makes an appreciable difference in the half yearly cost of working the engine. Of course, it is rather a fine point to say exactly how much oil is required to run any engine any distance under all conditions, but still, at the same time, one knows approximately what quantity should suffice for the day's work. Oil consumption is a matter of great concern to those in authority, and when the Author was working under a Divisional Superintendent the oil used was considered far in excess of the requirements, and instructions were given to fix a scale of allowances for the men. This was done, and the outcome of it was that the oil bill for that division alone fell to the appreciable extent of £1,700 per annum, and it may be said the number of hot bearings certainly did not increase, in fact, if anything a decrease was shown. This proves the absolute necessity of economy.

Before passing to the next heading, the Author would like to be permitted to state that he does not consider our present engineers attach sufficient importance to the lubrication of valves and cylinders. This is very evident by the fact that there is only one way of oiling these parts. It is granted our new pattern lubricator is the best device known for this purpose, but experience has shown that all lubricators, whatever the design, are liable to blockage, partial and even complete failure. If the latter happens just as the engine commences its journey the valves and cylinders have to work the whole day without lubrication ; and even in the case of a temporary failure the engine frequently runs a number of miles before the matter can be put right. This causes an incalculable amount of damage, and increases the consumption of fuel from 2 to 3lbs. per mile for the whole life of the valves. An additional or emergency lubricator should be fitted and connected directly with the steam chest, so that in the event of the present lubricator, which discharges the oil into the regulator box, failing, or, when an engine is running down a long incline with the steam off, the driver would be enabled to make use of the auxiliary lubricator, and so prevent damage which now arises from lack of lubrication.

Miles Travelled and Total Coal and Oil dealt with by an Engineman during the whole course of his Career.—Approximately, an engineman travels upwards of 1,500,000 miles on the footplate, and deals with 30,000 tons of coal and 7,500 gallons of oil. Of course these figures vary either way.

Time Spent in the Various Grades of Men.—The dominating factor in the advancement of men is promotion, and the rate of the latter depends entirely upon the conditions of trade. The number of years in the various grades, therefore, fluctuate accordingly. The following is a case which will give some idea, but which cannot be taken as typical of the whole. Cleaner, 3 years ; goods fireman, 6 ; passenger fireman, 3 ; engine turner, 3 ; goods engineman, 15, and passenger engineman, 15 years. Total length of service, 45 years.

Working of Compound Locomotives.—The Author has had considerable experience with the running of the De Glehn Compound engines in use on the Great Western Railway, and will give his opinion of the compound use of steam as applied to locomotives under present conditions. After reading and hearing of the extraordinary work done by compound engines all over the world, the Author was certainly influenced in their favour. As long ago as the seventies, particulars of Mr. Webb's L. & N.W. compound locomotive, and some wonderful performances were reported on this engine. Economy at that time was considered far more important than it is to-day. It was found, however, that the cost of coal per train mile was greater than the ordinary simple engine, but this did not affect the Author's opinion, as he had no details of the relative loads and cost in other directions, that is to say, for oil, repairs, etc., per ton carried. Since that date compound locomotives have been introduced on many railways both in the United Kingdom and abroad, but their adoption, as yet, cannot be regarded as anything like universal. The principle, as applicable to a locomotive, has also been extensively experimented upon and developed, and there is no doubt the De Glehn four-cylinder compound is the best of its kind yet produced. Theoretically, the advantages of compounds over non-compounds should be considerable, but, in actual practice, this has not been the case, in fact, under certain conditions, the effect was lost altogether.

Considering the subject from a mechanical, as well as from an economical standpoint, the author cannot speak too highly of the smooth and steady riding of the compound engines as compared with the two-cylinder simple expansion locomotives. This is due to the more perfect balancing and increased evenness of work done throughout the stroke. This, however, in the Author's opinion, can also be attained by four-cylinder simple expansion methods. The compound provides a large reserve of power, but the boiler, as now limited, will not ensure sufficient steam generation to make use of this power when it is most required, that is to say, when working heavy loads or up steep gradients. It is questionable, also, whether the adhesive weight would be sufficient, even if the full reserve power could be applied. It is found that the amount of condensation which takes place in the low pressure steam chest and cylinders is very great. This is proved by the large amount of water which continually issues through the low pressure piston glands. The Author has ridden on the gangway of the De Glehn engines when running upwards of sixty miles an hour and, in face of the high speed, water still came through the glands at every stroke of the piston. The fact is that, after the steam has done its work in the high pressure cylinders, it is exhausted in the low pressure steam chest at a considerably reduced temperature, and by the time it has been dealt with in the low pressure cylinders it is little better than water.

Turning to the question of economy, fuel and oil, although very important items, are not the only considerations, as the cost of maintenance has to be taken into account. Comparing the fuel consumption, the compounds are slightly cheaper than the non-compounds, but more expensive in oil. In regard to running repairs, the De Glehn engines have been somewhat heavy compared with our own. There are also the factory repairs to be considered. Taking all the various items collectively, the average cost per train mile of the compound is not cheaper than the non-compound.

Mr. Churchward's 4.4.2 and 4.6.0 classes of passenger engines will take a load of fifty tons in excess of the compound engines, so that we have yet to seek the reported advantages of the compound use of steam as applicable to locomotives.

It is only just, however, to qualify the results so far obtained. Our drivers have not had an extensive experience with compounds and, therefore, perhaps have not learned the best method of handling them and their peculiarities—the most economical type of fires with the comparatively light blast, and various other considerations which tend to further economy in fuel.

In regard to running repairs, here again the type of engine is different to that to which the fitters are usually accustomed, and, no doubt, the repairs are not completed as expeditiously as they might be on this account ; further, we have had the compound engines a short time only, so that it is a little premature to make a final decisive comparison.

Referring to the enginemen not being yet fully acquainted with the peculiarities of these engines, there is a difference of opinion existing as to the most effective and economical way of working the two gears. It is thought best by some to reduce the "cut off" in the low pressure, thereby increasing the steam pressure in the low pressure receiver. For instance, if the engine were working at thirty per cent. "cut off" on the high, and sixty per cent on the low pressure, and was hardly producing sufficient power to keep time with the train, it is contended that by reducing the "cut off" in the low pressure to forty per cent., additional power is obtained owing to the fact that the steam pressure in the low pressure steam chest immediately increases. Now the point to be proved is this. Does the increased pressure in the receiver, and consequently in the cylinder, but for a reduced distance, more than compensate the loss of power sustained owing to the shorter "cut off"? After a good deal of consideration and numerous tests, the Author is of opinion that it does not, and the following are the reasons :—

1. It is obvious that the back pressure, on the high pressure piston, is increased in the same ratio as the additional pressure in the receiver.
2. The expansive work required of the steam is increased. This steam, which, probably, is only about 60 lbs. pressure per square inch, and, therefore, at a comparatively low temperature, loses it energy before the piston gets to the end of its stroke ; in other words, the pressure is much too low to work effectively with long expansion.
3. The low pressure cylinder and piston are constructed to deal with low pressure steam, and this is not favourable to expansive working.
4. The condensation is increased.

Automatic Steam Brake.—It is a remarkable fact that many things which appear perfect in conception and design are not found so in actual practice. Some years ago, an automatic steam valve was fitted to all the ejectors with the object of putting on the steam brake at the same moment as the vacuum brake was applied to the train. Now, the theory that when the air valve was opened to apply the brake the air would rush into the top of the cylinder and force the piston down, thereby opening the valve and admitting steam into the steam brake cylinders, and so apply the brake, was correct. In practice, however, so far as the ordinary working of the brake was concerned, the brake did not act on the engine as it was supposed to do. The Author worked many Local Passenger trains, and ventures to state that in the 40 to 50 stops made daily the steam brake did not act once on the engine. There are two reasons for this, the first and most important being that when the air valve is opened to apply the vacuum brake it has to be closed again immediately, or the train would be pulled up too suddenly ; consequently, although the automatic steam valves duly open, immediately the air valve is shut, and before the brake has time to act, the steam valve closes also, owing to the action of the air pump which takes the pressure from the chamber and allows the piston to rise, thereby closing the steam brake valve. The second reason is that the brake is not quick acting owing to the condensation which occurs when the steam reaches the cold cylinders, and by the time the water has cleared the steam valve is closed. The latter is the cause of the frequent breaking of connections in emergency stops. The vacuum brake acts on and pulls up the train before the steam has taken effect in the steam brake cylinders. These points are now understood, and Mr. Churchward is fitting the vacuum brake to the latest built engines.

DISCUSSION.

Mr. G. H. Burrows, in opening the discussion, said he had to congratulate the Author on the very able way he had placed the subject before them. To some of them who were engaged on purely theoretical work it was of great assistance to have practical advice, and he hoped the paper would produce a good discussion. When referring to the question of lubricating cylinders and valves, the Author suggested that engineers did not consider that an important subject. He should like to disagree with him entirely. We wanted to get the most efficient lubricator, but this was difficult, for when steam was shut off there was nothing to carry the oil down into the cylinder and, consequently, when the engine was running down hill with the steam cut off, there was no oil for the valves. They had a lubricator passing through the shops which would work by a vacuum caused by the piston valve, and an automatic valve in the lubricator carried a little oil for each stroke of the piston valve ; this lubricator would shortly be made a subject for experiment. In connection with the French engine, the Author rather condemned the engine because the water got into the cylinders.

Personally, he thought it was not the fault of the compounding, it had more to do with the boiler. The water line was so near the top of the barrel that if steam was taken out in a large quantity it would lift the water into the steam pipe and thence into the cylinders. This was due to the design of the boiler.

The Author, referring to a lubricator being fitted with a vacuum valve, so that the piston would suck the oil from it, said that would not do. The point he emphasized was that they should have an extra lubricator in case the other one failed. In this case the automatic valve would not be of any use because the engine would be running with the steam on. With reference to condensation, the Author said that during some tests he had made he had occasion to be along the gangway when the boiler had been very low in water. The same thing had occurred, and the water still came from the piston glands even when the water had been so low in the boiler as to be very nearly dangerous, so that it could not be the boiler priming. He could not see Mr. Burrows' argument or the force of it.

Mr. C. T. Cuss asked what was the general cause of the failure of a lubricator?

The Author replied that a lubricator failed for the same reason that an engine sometimes failed. The real cause was very rarely found out.

Mr. C. T. Cuss, continuing, said he had known cases of engines being taken apart to find the cause of failure, but it did not seem to him that that should also be the case with lubricators.

The Author said nothing was perfect, and if the lubricator failed the driver should have another to fall back on, otherwise the engine might be obliged to run about 250 miles in a day without means of lubrication.

Mr. L. R. Dyer said the Author had not answered Mr. Cuss's question as he expected it to be answered. He wanted to know why. The answer was, however, that there was nothing perfect. Quoting Sir

Daniel Gooch's Diary, Mr. Dyer said "There is nothing perfect in this world, but my valve gear is mathematically perfect," and he thought that the lubricators designed by Mr. Churchward and others should come under the same heading, and there must be some good reason for their failure.

Mr. J. C. Crebbin : With regard to the firing on the Continent, the hump fire—only thicker under the door than was the English method—was usually adopted by the French enginemen. He had had two trips on the Belgian engines, where they were carrying out some very interesting experiments, but being so interested in the superheated steam and the pressure in the compound cylinders, he did not take much notice of the firing, but observed the formation from time to time, and that occasionally they threw on big briquettes without breaking them up. There was one great thing, he thought, on which Mr. Churchward and his assistants may congratulate themselves, and that was that the amount of the coal consumed per locomotive was very much less on the Great Western than on the London and South Western engines. This was all the more creditable as Mr. Drummond boasted that his boiler was the most economical locomotive boiler in this country. Referring to lubrication. Now, from all practical experience that one might gain in connection with various engines of different types, he did not think that they would ever get a perfect lubricator on locomotives until they used mechanical lubrication. During the last twelve months he had been interested in a small motor car on which had been fitted a sightfeed lubricator, with fair results. This was discarded for a Pony Rochester mechanical lubricator, and there had never been any trouble with these engines since. He thought the same thing might be applied to locomotives. He thoroughly believed that the French boiler was not to be compared with Mr. Churchward's taper boiler. The papers mentioned the De Glehn boilers as being the largest put on a locomotive, but, as a matter of fact, they were not. Taking the heating surface of that boiler, he ventured to think that they found it was much smaller than the heating surface of Mr. Churchward's types. He did not think there was a simple engine in the world that would accomplish the same work as the simple engine with piston valves of Mr. Churchward's design. There was a better expansion with these cylinders than with any other. Take, for instance, the new coupled passenger tank engines of the Great Northern Railway, which had huge cylinders and one of the smallest boilers adopted in this country. The beats of these engines were so erratic as to cause comments from outsiders, and it seemed to him that if they got an exhaust that beats first very loud and next very soft, there must be something radically wrong with regard to the steam distribution, proved by the fact that these engines burned three tons more coal per day than the 4.4.2 tanks with large boilers. He thought that with the long stroke cylinders and very efficient valves in use on the Great Western Railway, they had as near a compound engine as it was possible to obtain with a simple locomotive. He ventured to say the French design did not stand so good a chance with Mr. Churchward's simple engines as it would with those on any other line in England.

Mr. W. A. Stanier said, in his opinion, they should have a professor of firing in each division to train the firemen. There was no doubt that firing was an art, for everyone could not fire. Some were born and some were made, but if they had a professor of firing he could take charge of steaming the boiler while on the footplate and thus give the fireman advice and guide him. The Author mentioned the obedience of firemen. At present he ventured to say there were many cases where the fireman was master on the footplate, and it was partly brought about in this way. Promotion went by seniority and the shed foreman's reports as to the fireman's conduct, though he only knows whether he starts duty to time. In the Paddington division they got an expression of opinion from the enginemen, and if they had reason to doubt this an inspector went with the engine for three or four journeys, and this course tends to strengthen the engineman's hands.

With reference to the fire under the door to heat the air coming through the fire hole, they found that engines frequently would not burn their fire properly under the door, but this was overcome by setting the blast pipe an eighth of an inch forward.

Lubrication was a very important matter, and Mr. Burrows had mentioned the lubricators that had been fitted for experiment on the steam chests of engines. Engine No. 184 was fitted with a sight feed lubricator. There were also a number of engines with Furness lubricators. For the last two months those fitted with these lubricators had been lowest on the coal sheet. The mechanical lubricators fitted to engine No. 171 and the French engine lead to the steam chest and, as Mr. Crebbin had said, the oil supply should be regulated to a nicety.

But when engine No. 102 (French) was put into running order it had to run to Plymouth, the driver complained that by the time it got to Bristol his lubricator was empty. On examination, it was found to contain holes in the barrel about an eighth of an inch in diameter, the oil was sucked through the holes more quickly than the pumps should work it through. He did not know whether mechanical lubricators in the steam pipe would work more regularly. He thought that two-pipe lubricators were about as perfect a device as it was possible to get.

As regards compounding, the difficulty was with the steam. Either it condensed in the cylinder or the pressure was not maintained. There are very large smokeboxes on the French engines, which mean a very big cubical capacity from which to exhaust air ; the compound blast was very much softer than the simple engine blast and, in consequence, the fire did not burn so well. It seemed to him the most efficient compound to work was 35% H.P. and 65% L.P.

The French engines had a very fine valve gear for the distribution of steam. If there was any wear in the parts, it was reduced by the time it got to the valve. Our present engines, 4.6.0 and 4.4.2 types did not give so much trouble with the wear of the parts, but the "County" class with the short rods and wide angles have given trouble.

THE AUTHOR said, with regard to mechanical lubricators, they had had a lot of difficulty with the French lubricators fitted to the French engines. The great difficulty first experienced was that the oil became rather thick, and in cold weather almost solid, therefore they could not regulate it as desired.

Mr. J. C. CREBBIN said he had not had much experience with the French lubricator. The one he referred to was the American Pony Rochester. He believed the French lubricator was a different type. He still considered the future lubricator would be a mechanical one, for, as they knew, this was still in its infancy.

Mr. A. H. NASH : In a wet cylinder it is found that a pure mineral oil will not adhere to the surface. Wakefield's make a cylinder oil with five per cent. of tallow, and this adheres to a wet surface. Should the oil fail to adhere when passed to the cylinders it does no good at all.

Mr. W. A. Stanier : This has been the experience certainly at Paddington. We have found the cylinders and steam chests running dry with ordinary hydro-carbon cylinder oil. He did not know the constituents of Wakefield's oil, but certainly it gave very good results for cylinder lubrication.

Mr. C. K. Dumas said he was not an expert on lubrication, but should like to say something about compound locomotives. He had been fortunate enough to have a trip on "La France," and on a similar engine in France on the Northern Railway with trains of very similar weights and speeds and over practically similar roads, and he was very much struck with the difference in the method of working the engines. In the first place, in regard to the fire, in England the engine was run with the back damper open and the front closed. In France exactly the opposite practice was adopted, the front damper being open. As to the shape of fire in England, the firemen adopted the hump fire, but in France they used, as near as they could get, a level fire, rather higher in the back corners and under the door.

With respect to the cut off, in England the driver started with both pairs of cylinders in full gear, then he notched up the H.P. to 30 per cent. up from the L.P., after which he locked the gears for the two pairs of cylinders together, and when subsequently changing the gear shifted both of them at the same time. In France, the drivers notched up only on the H.P. cylinders and kept the L.P. the same cut-off, about 65 per cent. throughout the run.

In England the regulator was kept full open and the working of the engine adjusted by means of the reversing gear. In France the H.P. cut-off was varied according to the speed, and the engine worked with the regulator.

In England, also, the engine was run non-compound for a few strokes at starting and afterwards worked compound, but in getting away after starting and after all slacks live steam was admitted to the receiver to help the L.P. steam.

In France the engine was always run non-compound at starting, but after the first few strokes it was compounded, and live steam was never admitted to the receiver when so working.

The Author : Would you tell us the class of coal used?

Mr. C. K. Dumas : About 75 per cent. of it looked like poor Welsh coal ; it was some kind of French coal, and the other 25 per cent. consisted of briquettes.

The Author : The fire must be worked according to the class of coal. The Frenchmen would find it different working their engines with Ebbw Vale coal. As to the cut off, he hardly considered 75 per cent. desirable, as it was not economical, but the French did not study economy. Mr. Dumas said the Frenchmen ran with both dampers open. If the front damper only was used the coal in the back of the firebox would not burn as it gets no draught. He could not understand that any engine driver in England would work the front damper closed. He failed to see how it was possible, as he had fired about 5,000 tons of coal on the French engine himself, and had always found that working with both dampers open was the best.

Mr. W. O. Chalk said he thought the cause of inefficient working of compounds was saturated steam. Saturated steam was the most inefficient means of utilising steam in a cylinder. He should like the Author to tell him the result of the trial of the automatic stokers ; he believed they were condemned. On Continental engines there was a flap to control draughts on the chimneys; was this preferable?

The Author said he did not think it was the accumulation of water absolutely ; it was saturated steam which was carried away and, therefore, the automatic cocks would be of no use even if they worked. They were liable to failure, and he did not think they would be of any service to the compound.

Mr. Chalk : In marine engine practice steam receivers were provided. The continuous running of engines was of the utmost importance, and he did not see why it was impossible: to make them answer for locomotive working.

The Author : Has not Mr. Chalk overlooked the fact that the speed is altogether different on a locomotive than on a marine engine? As to the mechanical stoker, he was of opinion that it was no use whatever for locomotive working. It would do for a stationary boiler where the working was constant, but on a locomotive it was altogether different. The mechanical stoker would get steam for about eighteen miles and then it would go all wrong.

Mr. C. T. Cuss considered that the mechanical stoker should be only used for the power required to put the coal in, and the skill and mind should be the same as that which regulated the running of the engine. Mr. Smith mentioned an improved water scoop which balanced. I shall be glad to know if the improvement was only in the balance or whether it was in the shape, which would effect the saving of waste of water.

The Author said he could not say that it would prevent the waste of water. It was much easier to work, and it could be pulled up much quicker. It would not save the wash, but as it could more easily be pulled out of the water it would save the overflow of the tank.

Mr. H. C. Rodda : The top of the scoop was so cut back to catch the crest of the wave. Also the scoop was so constructed that on its first movement it was made to slide down the column of water, thereby disconnecting itself from the top casting, and the water was released between the water scoop and the top casting.

Mr. W. A. Stanier said he thought that the principal difficulty with the mechanical stokers was the varying classes of coal and the varying sizes used on the same journey, which prevented the engine driver from getting the deflector plates the right size.

The Author : The flap on the top of the chimney, mentioned by Mr. Chalk, was for standing purposes ; it blanked the fire. He did not recommend it, as injury was done to the boiler and firebox, and it always caused the tubes to start leaking.

Mr. Rodda said he believed in America they were used to retard the cooling of the boiler.