OIL-BURNING LOCOMOTIVES ON THE TEHUANTEPEC NATIONAL RAILROAD, MEXICO.*

BY MR. R. GODFREY ASTON, *Graduate*,
OF RINCÓN ANTONIO, OAX., MEXICO.

The object of this Paper is to give an account of liquid-fuel burning in the locomotives of the Tehuantepec National Railroad, showing some of its advantages over coal, and giving a general description of facilities for handling and storing this fuel-oil, the methods of burning it, and a few results gained which are taken from the monthly performance of locomotives. The author does not intend to deal fully with costs, etc., as it is too large a subject for so short a Paper, but will confine himself to a more practical point of view.

The Tehuantepec Railroad is a trans-continental line of standard gauge (4 feet 8½ inches), 304 km. (189 miles) long, running across the Mexican Isthmus of Tehuantepec from the port of Puerto Mexico (Coatzacoalcos) on the Atlantic, to the port of Salina Cruz on the Pacific, with grades varying from level to 2·15 per cent., and abounding in curves up to 11° 28″, or 100·10 metres radius, and where the speed of trains is limited to 24 km. (15 miles) per hour.

* *See* Papers by Thomas Urquhart (*M.*) in Proceedings 1884, page 272; and 1889, page 36; also Paper by Louis Greaven (*M.*) in Proceedings 1906, Part 2, page 265.

4 A

Storage Facilities.—All fuel-oil for the Company is received at the terminal of Puerto Mexico, where the main storage-tanks are situated; these comprise three cylindrical steel tanks, each composed of six tiers of steel plates riveted together and a light steel roof, with three manholes, and a ventilator in the middle through which gases arising from the oil can escape. Two of these tanks are 95 feet diameter and 37 feet 6 inches deep, each with a capacity of 46,996 barrels of 42 United States gallons (35 British gallons).* The third tank is 92 feet diameter and 29 feet 9 inches deep and has a capacity of 35,138 U.S. barrels.

These tanks are all enclosed in separate earthen embankments and are connected together by an 8-inch pipe-line, which enters the tanks 1 foot 6 inches from the bottom, this space being required for water, etc., settling out of the oil and which can be drawn off through a 3-inch valve at the bottom of the tank. The pipe-line runs down to the wharf, where it is fitted with an 8-inch check-valve, and it is from here that vessels delivering cargoes of oil can pump straight into any tank, the two largest tanks being about 2 km. ($1\frac{1}{4}$ miles) from the wharf. At convenient places in the pipe-line near to the round-house are stand-columns for filling engine-tanks, tank-cars, etc., and near the round-house is also a supply tank of 28,000 U.S. gallons capacity, erected upon a structural steel frame, also used for giving oil to engines, etc.

The terminal of Salina Cruz is laid out in the same manner, except that there are only two storage-tanks, 95 feet diameter and 37 feet 6 inches deep, of 46,996 barrels capacity. The capacity of all these storage-tanks has been calculated out in U.S. barrels of 42 gallons for every 6 inches of depth, allowance being made for all internal stays, supports, etc. The fuel-oil is shipped from Puerto Mexico to the other fuel-stations in specially constructed double-truck steel-frame tank-cars of 6,600 U.S. gallons capacity, the gallons per inch of depth of these cars being known, so that

---

* 1 U.S. gallon = 231 cubic inches. 1 British gallon = 277·27 cubic inches. U.S. gallon = $\frac{5}{6}$ British Imperial gallon. The value of the Mexican dollar is assumed throughout this Paper to be 2*s*.

the exact amount contained in each car can be credited to the station to which it is shipped.

Fuel-Oil.—The fuel-oil used by this Company is purchased from the Texas Company of Port Arthur, Texas, at about 97½ cents gold, per barrel of 42 U.S. gallons delivered at Puerto Mexico, and pumped into the Railroad Company's tanks by the delivering vessel. This fuel-oil is generally delivered in tank-steamers, sometimes towing barges, which come right up alongside the Railroad Company's wharf; the coupling between the vessel and the Company's land pipe-line is made with a flexible rubber or steel hose, which is supplied by the vessel.

This fuel-oil is quite thin and flows readily through pipes of any diameter; it is sometimes nearly black in colour, and sometimes a dark brown with a green fluorescence. The Railroad Company stipulates in its contracts with the Texas Company that the flash-point (closed) shall not be under 110° F., as a lower flash-point than this is liable to be dangerous on account of the volatile gases and fumes which arise from the oil at comparatively low temperatures, and which the author has seen catch fire from a torch which was some 10 or 12 feet away from the oil. Some oils may be used in the crude state as fuel, while others have to be passed through the refinery; after the lighter oils, etc., have been taken off, the by-product or residuum is used in a satisfactory manner as fuel, and as such has been and is used in Mexico. Fuel-oil contains no power of spontaneous combustion, and unlike coal does not deteriorate if stored in tanks or reservoirs.

The specific gravity of this oil varies from 0·790 to about 0·942 and its weight per U.S. gallon from 6·4 to 7·75 lb. The British Thermal Units vary from 17,000 to 20,000 per lb., the average being from 19,500 to 19,800, and between this and the best steam-coal there is a very great difference. The analysis of two samples of the oil as used by this Company for fuel is as follows:—

Specific Gravity @ 60° F. .	0·931	0·881
Beaumé „ @ „ .	20·5°	29°
Flash-Point (closed) . .	130° F.	135° F.
„ „ (open) . .	160° F.	160° F.

4 A 2

Fire Test	220° F.	224° F.
Setting Point	3° F.	20° F.
Viscosity @ 100° F.	200 seconds (Redwood)	78 seconds (Redwood)
Sulphur	0·77 per cent.	0·26 per cent.
Calorific Value	10,688 calories	11,000 calories
Colour	Dark brown	Dark brown
Water and Dirt	1 per cent.	0·25 per cent.

The standard temperature for the measurement of fuel-oil is 60° F., and expansion is allowed for at the rate of 1 per cent. for every 20° F. increase in temperature above 60° F., and contraction at the same rate for decrease in temperature below 60° F.

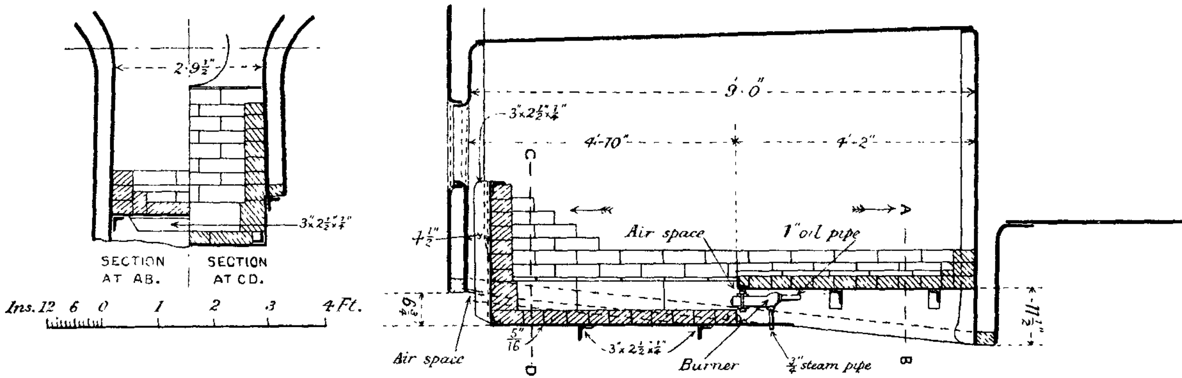
Locomotives.—The locomotives in use on this road are of the Baldwin consolidation type, the main dimensions of which are :—

Cylinders	20 inches by 26 inches.
Wheels (drivers)	53 inches diameter on tread.
Fire-box	Length inside, 108 inches; width inside, 33½ inches.
Flues	239 of 2 inches outside diameter.
Grate area	24·94 square feet.
Heating surface	Fire-box, 147; flues, 1,700. Total, 1,847 square feet.
Boiler pressure	170 lb. per square inch.

The oil-tank is fitted into the coal space of the tender, and its contents calculated for every half-inch of depth; most oil-tanks have a capacity of 2,000 gallons, and the oil is fed from the tank to the burner or atomizer through suitable connections and flexible brass ball-joints.

Fire-Box Arrangement.—The Company's practice, after trying various types of burners and atomizers, is to use what is called a front-end burner, Fig. 1, that is, the burner mouth points towards the back of the fire-box or fire-box door-plate; the burner is placed in a 9-foot fire-box, 4 feet 2 inches from the flue-sheet, the flame playing against a brick wall built up to the level of the fire-box door opening. Between this brick wall and the fire-box back-plate is a 4-inch air-space extending the whole width of the fire-box and right up to the top of the brick wall. Brick walls are built up on each side of the fire-box from the height of the brick wall at the back, Tehuantepec National Railroad.

FIG. 1.—*Front-end Oil-fuel Burner arranged in Locomotive Fire-box.*



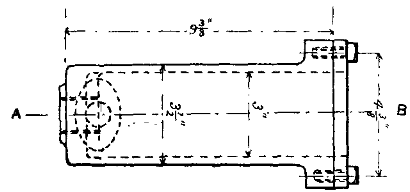
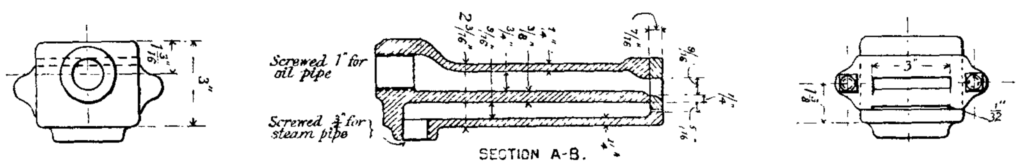


FIG. 2.
Locomotive Oil-Burner or Atomizer.

Made by the Company.



gradually sloping downwards; the floor of the grate or ash-pan is laid all over with fire-brick. No brick arch or baffle-plate is used.

As mentioned in the preceding paragraph, the burner is placed 4 feet 2 inches from the flue-sheet, and midway between the sides of the fire-box, so that both in front and behind the burner or atomizer there is a flat bricked-over area of fire-grate; and as the burner is placed parallel to the lower grate, there is a 4-inch space between the front and back grates, this 4-inch space being left open to admit air, extending from one side of the fire-box to the other.

Brickwork.—This should be of the very best material and workmanship, as it is subject to a much greater heat than from a coal fire; if this is not done, the walls will not stand, and engine failures will occur, moreover the failure of only one brick will perhaps necessitate new brickwork throughout, thus needlessly running up expenses. There is no reason why the brickwork should not stand from four to six months, and perhaps longer, if due care be taken from the start.

A good brick should contain about 80 to 85 per cent. of silica and from 20 to 15 per cent. of alumina, and should be as free as possible from alkalies, which cause fluxing. A good brick becomes surface-glazed though remaining rough and porous: it should be perfectly dry when built up in a fire-box, otherwise the heat will cause it to crack; if possible, the fire-bricks should be fired at a temperature as high as that to which they will be exposed when in use.

Burner or Atomizer.—There are many and various kinds of hydro-carbon burners, and after a trial of various types, including the "Baldwin" and "Best" burners, this Company is using with considerable success a burner which is made in their own shops, and which is really an inverted "Best" burner, Fig. 2 (page 1027). It is a simple device which allows the oil to fall from an orifice 3 inches wide by $\frac{9}{16}$-inch deep over the top of a flat steam-jet

3 inches wide and $\frac{1}{32}$-inch deep, the steam picking up the oil and sending it into the fire-box in the form of a spray; the underneath jet of steam delivers the spray of oil at an angle, so that it strikes the brick wall in the middle, instead of shooting out from the burner parallel with the bottom of the ash-pan. This burner may be called an outside atomizer, and although it is in general use it has its drawbacks; but it has been found to be more efficient than any other they have used.

The most essential points about a burner or atomizer are :—

(1) Its atomizing capacity. All fuel-oil is heavy, and will burn in the form of a vapour or spray only when mixed with air. The object should be to fill the fire-box with a soft and voluminous flame, and not to impinge it in any one place.

(2) Its facility for keeping clean and free from clogging.

(3) Its adjustability in giving the right direction to the flame or spray, and regulating the proper proportion of oil and the agent, either steam or air, used for atomizing.

A burner which will vaporize or atomize the oil at the point of expansion of the agent used for that purpose, and which is easily handled, and which will atomize the greatest amount of fuel with the least possible energy, is the highest and most efficient that can be designed. On this railway, steam is used as the atomizing agent, because, after various experiments, it was found to be superior to air. The steam to a very great extent heats the oil as it flows into the burner before delivery in the form of a vapour spray. The flame from the burner should not be too long or it will pass into the flues and become extinguished. Gases which are only partly consumed will relight in the smoke-box.

Lighting up an Oil-Burning Engine.—In each round-house of this Company is a stationary boiler, always in steam, used for the washout and other pumps, as well as for lighting up dead engines. From this boiler is laid a 2-inch steam-line to points between each engine road or stall. From there a connection can be made to a locomotive through a 3-way cock, or T piece in the steam-pipe leading from the steam stand on top of the fire-box to the burner; by use of this steam the burner can be started and kept going until the boiler has generated enough steam to keep the burner going itself. A piece of oily waste is lighted and thrown into the fire-box just in front of the burner from which the spray ignites. Connections can be made to any other engine all ready in steam, should the stationary boiler not be available for any reason.

Firing and Cleaning Flues on Road.—With an oil-burning engine there is always a fire of equal intensity and one which never gets dirty, so that good steaming is practically ensured. It is a popular idea that it is a very easy matter to fire an oil-burning engine, but this is not the case, as both skill and care are required, so that the author thinks it best to lay down a few of the most important rules:—

(1) See that the oil-tank is full, and if heaters are used, that they are in operation, and that the temperature of the oil is as it should be.

(2) See that the sand-box on the foot-plate is full, and that the scoop is in its place.

(3) Before starting the fire, see if the temperature of the fire-box is below igniting point, which is a dull red, and if so, open dampers (if used), start the blower, and open the atomizer-valve fairly hard; then put a piece of saturated oily waste on the bottom of the grate after setting it alight, close the dampers (if used) and fire-box door, and turn on the oil very light. When the oil has ignited, reduce the blower and atomizer to a light feed, also the oil until the chimney is quite clear of smoke.

(4) See that the fire is burning brightly, and that there is no oil on the bottom of the pan, also that the brickwork is in good condition, and that no bricks or any other obstructions are on the bottom of the grate or pan so as to obstruct the flame or jet on its way from the burner to the brick wall.

(5) As regards cleaning flues on road, it is best to sand frequently if the engine is being worked hard, say every

15 or 20 km. (9 or 12½ miles), but if the engine is being worked light, every 50 or 60 km. (31 or 37 miles) will be sufficient.

(6) Having attained a fair rate of speed, fill the scoop with about a quart of sand, close dampers (if used) and put reverse-lever near full stroke, then open regulator wide, insert the end of the scoop in the round hole in the fire-box door, and allow the sand to be drawn out of the scoop through the fire-box and flues and out of the chimney; sanding is best done when the engine is working hard up a grade.

(7) Black smoke shows incomplete combustion, and should never be allowed to be emitted from the chimney, as it only fills up the flues with carbon, besides being a non-conductor of heat, and it is also a great waste of fuel. If a bluish-coloured smoke or fumes are seen coming from the chimney, it is a sign that the burner is cut down too fine.

(8) When putting out the fire, the oil-valve should always be closed first, then the atomizer-valve (in their case, steam), then the blower. The oil-valve is always the last to be turned on, and the first to be turned off.

(9) Never go near an open tank with a lighted lamp or torch, as at any time an explosion may occur, especially if the oil used has a low flash-point.

Round-House or Shed Work.—An oil-burning engine has a great many advantages over a coal-burner, but this is specially noticed in the round-house or shed when squaring up an engine after a day's run; there are no fires to be raked out, no flues or smoke-box to be cleaned (the smoke-box door of an oil-burning engine need be opened only once every three or four months for cleaning purposes); there is no coal to be sacked, weighed, or otherwise handled, and oil-burning engines do not carry fire-rakes, prickers, flue-brushes, shovels or picks, so that all these things, besides other minor details, represent a great saving in engine equipment.

Among other advantages are the rapidity with which steam can be raised, and the facility with which the boiler can be forced when greater calls are made; the author has in a special case of necessity raised steam in a dead engine to a pressure of 130 lb. per square inch in 50 minutes from cold water, without any serious effects on the boiler, whereas in a coal-burner from 2 to 3½ hours is needed to raise steam if no jet from a live engine is used.

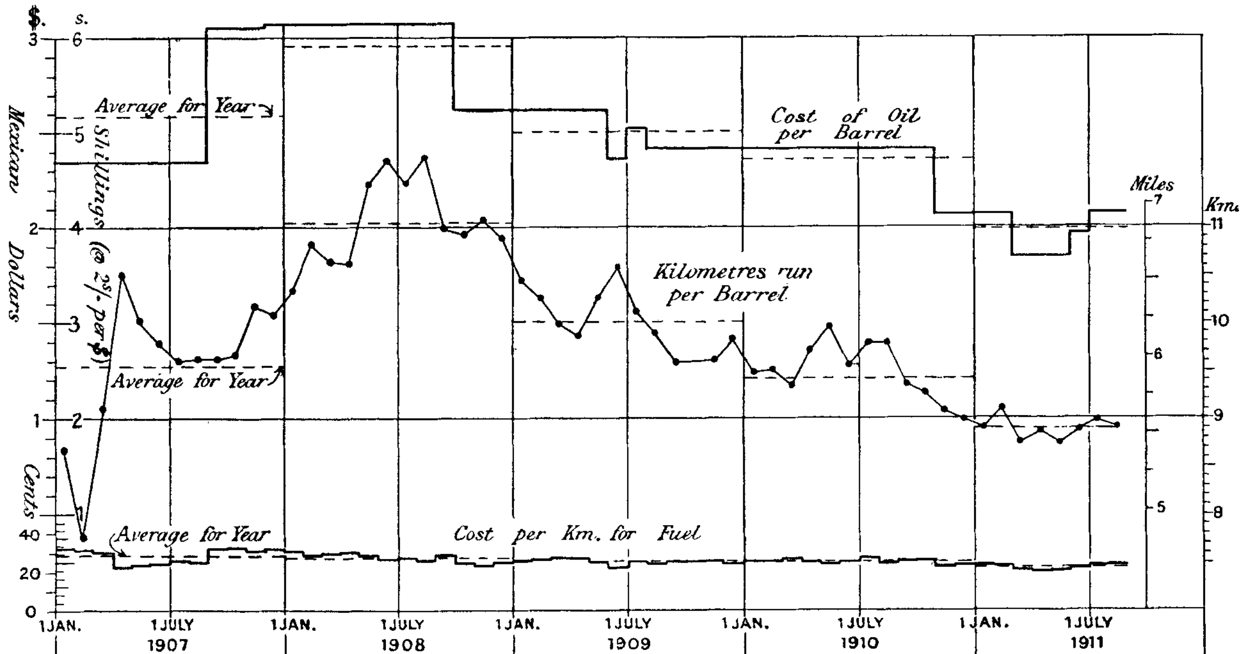
Another very great advantage is in switching, or shunting, or standing pilot, when engines frequently have to stand in steam for hours at a time. The burner can then be cut down or extinguished, thus effecting a great saving in fuel, as an engine will always retain a sufficient amount of steam to start the burner or atomizer again, and any danger of the fire-box or crown-sheet being injured through the water getting too low is entirely obviated. The heat lost while standing is the same whether coal-fired or oil-fired.

Effects of Oil-Burning on Fire-Box, Flues, etc.—Oil burning is no more injurious to a fire-box or flues, etc., if ordinary care be used, than coal burning; in fact, from the author's experience it is not so hard on a fire-box as coal burning, for it is quite noticeable in the fire-boxes of coal-burning engines that stay-heads, plate edges, flue-ends, and crown bolt-heads show signs of wear, corrosion or burning, but in their oldest oil-burning engine not any of these signs are noticeable, everything being clean and in good condition.

This Company uses steel boxes with wrought-iron tubes and copper ferrules. A set of tubes will last and remain perfectly tight from two-and-a-half to three-and-a-half years, when they may have to be taken out to be re-ended; some of the engines are working to-day with tubes over four years old, many of which are as tight as the day they were put in. Some of the wrought-iron tubes are being replaced by mild steel, because, after the holes in the tube-sheet get worn, tubes of steel stand the expanding better; but at present those that are in service have not been in use long enough for one to form an opinion of them as compared with wrought-iron.

Tehuantepec National Railroad.

FIG. 3.—*Diagram showing Cost of Fuel-oil and Distance run per Barrel from January 1907 to August 1911.*



Some people are of the opinion that more than 2 per cent. of sulphur in fuel-oil is injurious to the fire-box, but as the amount of sulphur in the Texas oil the Company has been using is below 0·75 per cent. no ill-effects have been noticed; but as there are coals which show as high as 3·5 per cent., the author does not see why sulphur should be more injurious in oil than in coal.

Engine Performance.—Although the engine tonnage has practically doubled since 1908, the author gives the following statistics, Fig. 3, for every month from January 1907 to August 1911:—

(1) Cost of fuel-oil per barrel of 42 gallons (Mexican currency);

(2) Cost per kilometre for fuel (Mexican currency); and

(3) Kilometres run per barrel of oil,

but it must be understood that since about the middle of 1909 all engines are loaded down to their capacity, single trains averaging 750 to 800 tons behind the drawbar. As the road-bed is by no means level, helper engines are used over certain sections where the grades are long and heavy, so that this will explain the decrease in kilometres run per barrel of oil between 1908, 1909, 1910, 1911, as the tonnage per engine has been increased to the maximum.

Oil-Fuel. Monthly Averages.

During	Cost of Oil per barrel.		Cost for Fuel.		Distance run per barrel.	
	Dollars (Mexican).	Shillings.	Cents per km.	Pence per mile.	Km.	Miles.
1907	2·585	5·17	28·476	10·99	9·546	5·928
1908	2·957	5·91	27·151	10·48	11·04	6·855
1909	2·502	5·01	25·19	9·73	9·999	6·209
1910	2·356	4·71	25·02	9·66	9·41	5·843
1911 (8 months)	1·990	3·98	22·23	8·58	8·89	5·520

The cost of fuel-oil per barrel of 42 U.S. gallons (231 cubic inches) as charged out every month is made up of the following items, and also depends upon whether there is any shortage or overage when the inventory is taken at midnight on the last day of each month; this accounts for the variation in prices:—

(1) Price of oil per barrel f.o.b. in ships' tanks at delivering port (Puerto Mexico).

(2) Commission to purchasing agents in United States.

(3) Consular invoices.

(4) Inspection fees for inspecting cargo in ships' tanks at shipping port.

(5) Stamps.

Items 2, 3, and 4 only refer to oil purchased out of Mexico.

Based on tests which have been made, the Company reckons three-and-a-half barrels, or 147 U.S. gallons, of oil as being equal to one ton of coal or 1,000 kilograms, or 2,204 lb. or three-and-a-half barrels of oil equal one unit of fuel.

The author is unable at this time to give any reliable data of fuel consumption on a tonnage basis, as no records are kept of Company freight hauled over the road, which is considerable, but the average loaded passenger and freight cars hauled one kilometre per unit of fuel from January 1st to December 31st 1910 was 330·89, and from January 1st to June 30th 1911 was 333·60. The average loading weight of freight cars is approximately 30 tons.

In August this year (1911) the Company received the first cargo of a native or Mexican fuel-oil under a contract with the "Campañia Mexicana de Petroleo," El Aguila, S.A., at a price of $1·75 (Mexican) (3*s*. 6*d*.) per barrel of 42 U.S. gallons delivered into Railroad Company's tanks at Puerto Mexico. This oil, which is used in its crude state as fuel, is jet black in colour, thick, and has a heavy asphalt base, and although the Company has not used it sufficiently long to be able to compare it with the Texas oil, it may be of interest to state a few of the difficulties met with when first they began to use it.

As this oil is thicker than Texas oil, heaters have to be used in the engine-tanks, but it has been found that if this oil is heated up to about 150° F. (which can be done with Texas oil), great difficulty is experienced in getting the burner spray to light, and that the oil settled very thickly at the bottom of the tank; it would not run through the pipes to the burner, and could only be burnt effectively by mixing a fresh supply of oil with it. In order to burn this Mexican native oil successfully, it requires to be only just warmed. When using this, a large piece of carbon or cokelike substance is formed in the fire-box, and grows up from the bottom of the pan or grate directly under the burner-mouth. This may vary from 6 by 4 by 4 inches to 12 by 10 by 8 inches in size, growing up in such a manner as almost to smother the burner-mouth. The analysis of this substance is as follows:—

Ash	1·25 per cent.
Sulphur	7·89 ,,
Carbon	90·86 ,,
Asphalt	nil.

It shows to a certain extent that there is incomplete combustion, which can be remedied by admitting more air; but this cannot very well be done without affecting the steaming qualities of the engines. However, by raising the burner slightly these lumps of carbon have decreased in size, and it is hoped eventually to adjust things in such a manner as to prevent their forming at all.

The analysis of two cargoes of this Mexican crude fuel-oil is as follows:—

	No. 1.	No. 2.
Specific Gravity @ 60° F. .	0·944	0·942
Beaumé ,, @ ,, .	18·4°	18·8°
Flash-Point (closed) . .	78° F.	102° F.
,, ,, (open) . .	104° F.	120° F.
Fire Test	165° F.	180° F.
Viscosity @ 100° F. . .	1,080 seconds (Redwood)	920 seconds (Redwood)
Sulphur	3·44 per cent.	3·35 per cent.
Calorific Value . . .	10,971 calories	10,610 calories
Colour	Black	Black
Water	nil.	0·5 per cent.
Asphalt		37 ,,
Carbon (coke) . . .		12 ,,

It may be explained that the 37 per cent. asphalt is obtained by distilling off the distillates from the crude until only 37 per cent. residue is left, which consists of asphalt. The 12 per cent. coke is obtained by distilling this 37 per cent. down to 12 per cent. residue (on the crude), so that if they get 37 per cent. asphalt, they do not get the 12 per cent. coke, and if they get the 12 per cent. coke, they do not get the 37 per cent. asphalt.

The author regrets that at this time he is unable to go deeper into this subject, but he hopes that what little information he has been able to give with regard to oil-fuel burning in the Tehuantepec locomotives will be of interest to others working in the same direction.

The Paper is illustrated by 3 Figs. in the letterpress.

Discussion.

The PRESIDENT, in moving a hearty vote of thanks to the author, said that he would like to mention how glad the Council were to be able to accept a Paper written by one of the Graduates, dealing with his own professional experience, and the first of its kind.

The motion was carried with acclamation.

Mr. T. O. MEIN (Great Eastern Railway), in opening the discussion, said he was sorry that their Locomotive Superintendent, Mr. S. D. Holden, was unable to be present owing to an important previous engagement, and he (the speaker) had therefore been requested to attend and represent Mr. Holden on the present occasion. In the first place, he desired to congratulate the author upon the excellency of his Paper and the evident efficiency of the railway upon which he was employed, because he noticed that the tubes remained tight from 2½ to 3 years. The burner which had

(Mr. T. O. Mein.)
been adopted by the Tehuantepec Railroad Co. was what was known as the "Best" burner, or an inverted type of the "Best" burner, an illustration of which was shown in the Paper. The oil fell and came in contact with a slice of steam, so that the oil was practically shovelled into the fire-box. The essential point, as the author pointed out, for a liquid-fuel burner was that it should thoroughly and completely atomize the fuel. Reference was made on page 1036 to the fact that when using the Mexican native oil "a large piece of carbon or cokelike substance is formed in the fire-box, and grows up from the bottom of the pan or grate directly under the burner-mouth." It appeared from this that complete combustion did not take place. To get complete combustion it was necessary to have complete atomization, and if that was really effected by the burner used, the cokelike formation would not appear.

Liquid fuel had been used on the Great Eastern Railway for a great number of years.* He said "had been" advisedly, because the cost of liquid fuel was the only bar to its greater use in this country. When it was borne in mind that the freight from the oil-fields was from 20*s.* to 21*s.* per ton, that the evaporative efficiency of the oil when used in the boiler was about 14 lb. of water per lb. of fuel as against, approximately, 8 lb. of water for 1 lb. of coal, it would be seen that, apart from all the many advantages that were obtained by the burning of liquid fuel, a limit had been reached which made it almost impossible to burn it economically in this country. Apart from the freight, there were also the storage and conveyance of the oil from the port at which it was received, and also the cost of the oil had to be taken into consideration.

The advantages of burning liquid fuel were many. From a locomotive point of view there was not, as the author had pointed out, the same wear and tear on the fire-box plates, because the scarifying action of the moving fuel due to the sharpness of the blast necessary for the proper combustion, if a large amount of

---

* Proc. Institution of Civil Engineers, 1910-11, Part III, page 340.

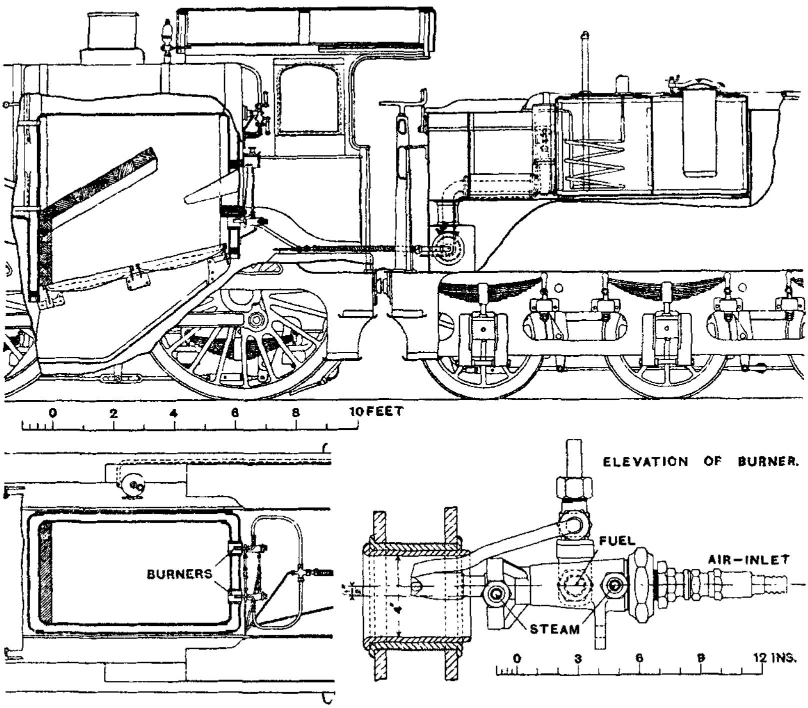
work was required to be done, did not take place, and consequently a blast-pipe with a much larger orifice could be used, with consequent reduction in back-pressure in the cylinders; and in this way a better result would be obtained from the engines. Another point of importance was that there was an absence of smoke when the admission of air, steam, and fuel were properly regulated, and the very objectionable practice of the emission of sparks, which was now such a serious matter for railway companies, was prevented. Another factor was the economy of labour which resulted, because the firemen had not to shift from 40 to 45 lb. of coal every mile run by the engine. A more rapid steam generation could also be obtained, and there was saving in weight and storage room. When the higher calorific value of liquid fuel as compared with coal was borne in mind, it would easily be understood that it was not necessary to carry so much weight on the engine or tender.

He thought it would be of interest to the members if he showed a specimen of the "Holden" form of burner or injector used on the Great Eastern Railway, Fig. 4 (page 1040). It would be noticed that at one side towards the back end, steam was admitted through a union into an annular chamber from which it passed through four holes into the space between the inside and middle cones, and then along to the end of the inner cone. The fuel was admitted through a regulating valve on the opposite side to the steam inlet and passed along between the outside of the middle cone and the casing of the burner, so that the steam and fuel mingled at the ends of the cones. At the same time, owing to the formation of the cones, air was induced through the central hole. The end of the central cone was open, and air was admitted through it, so that at the opposite end of the cone air, steam and fuel were mingled, and passed out of the nozzle in the form of spray. The ring-blower, which could be seen in the front surrounding the nozzle, was used for pulverizing and further atomizing the spray from the nozzle. There were three small holes at the bottom and two at the top of the blower. The bottom holes were so drilled that the steam from them struck the mixture about 6 inches from the nozzle in an

(Mr. T. O. Mein.)

angular direction. The holes at the top were not sloped but were drilled parallel with the centre of the burner. It was claimed that, in addition to breaking up the mixture, a spiral motion was also imparted to it. There was also an auxiliary supply for fuel, so that the special feature of the "Best" burner was practically obtained,

FIG. 4.—*General Arrangement of Liquid-Fuel Burning Apparatus* (Holden) *on Four-Coupled Express Engine. Great Eastern Railway.*



apart from the particular features of the "Holden" burner itself. This auxiliary supply of fuel could be used, provided it was not possible to get sufficient through the body of the injector. The fuel from the auxiliary pipe fell on the outside of the spray issuing from the nozzle, and it was sprayed practically in the same way as was done by the burner referred to by the author.

Another feature he wished to refer to was that, inserted into the air-inlet at the back of the burner, was a small fitting containing a ball in a pocket and also a seating. The air induced through the centre of the injector could be utilized, if the vacuum brake was fitted to maintain the vacuum in the train-pipe, and thus take the place of the small ejector. The train-pipe connection was made to the end of the fitting, and the air was sucked through the pipe. Directly the injector was stopped working, the ball fell back upon its seat and sealed the vacuum in the pipe. This fitting was simply a small addition to the injector. The quantity of fuel which could be passed through an injector of this kind was about 80 gallons per hour, and with this quantity it was found an engine could be run with even the heaviest trains. The longest run made with an express engine was about 532 miles without the fire being cleaned, and the engine might have run even a longer distance if it had been required. The boilers which had been fitted were usually provided with the ordinary fire-grate, so that it was possible to change immediately from oil to coal fuel. A small layer of incandescent solid fuel was always provided for the ignition of the liquid fuel. Furnaces lined with brickwork, such as rivet furnaces and furnaces for melting metal, had been fitted with the apparatus, and many, if not most, types of stationary boilers.

Mr. F. N. POIGNAND said there was a great deal in the Paper which was exceedingly interesting to him, as during the time he spent in America he was engaged on the design of quite a number of oil-burning locomotives. Several locomotives have been fitted with oil-burning apparatus in America, but only in the western and south-western part of the States. The only railways which had decided to use oil were those which were a long distance from a coalfield, and had means of obtaining a large quantity of liquid fuel at a very cheap rate. With regard to the Tehuantepec Railroad, he noticed their coal consumption on a Baldwin 20-inch by 26-inch cylinder engine, with a grate area of 24·8 square feet, was 89·6 lb. per mile, at a cost of 13·8*d.*, and that when they first started burning oil they used 9 gallons of oil to the mile, equal to 67·5 lb.

(Mr. F. N. Poignand.)
at a cost of 10·7*d*., but during the period covered by Mr. Aston's Paper the average price of oil per barrel increased to 5*s*. per barrel, at which price the cost per engine-mile would have worked out at 12·8*d*. At this rate there would not have been much saving in liquid fuel. It had been found that, covering about 2,000 locomotives in America, if a short ton of coal, 2,000 lb., cost more than three times that of a barrel of oil, it was profitable to use oil, otherwise the question was not worth consideration. Those figures were based on the fact that all economies, such as terminal charges, were taken into consideration. Oil-fuel if used exclusively might introduce a considerable saving, but where both oil and coal engines were used, the opportunity of saving was reduced, because not only was it necessary to have oil-tanks which were expensive to maintain, and to pump oil into the tanks, but it was also necessary to maintain coal chutes.

Another thing to be borne in mind was that, if an oil-tank was put alongside a round-house in America, the insurance company would immediately insist on the tank being taken down. They would not allow an oil-tank to be put within 30 yards of a building of any description. Oil-tanks if they once caught fire were doomed, but if a coal chute caught on fire (and, as the members knew, coal chutes were very subject to the chance of catching fire) there was some chance of saving it. There was one way in which it was possible to prevent an oil-tank being totally destroyed by fire. If the tank was entirely covered so that it could be made air-tight at short notice, and steam was then injected into the top of the tank, it was very often possible to put a fire out, but it was necessary to be quick about it.

He noticed that the cost of changing locomotives on the Tehuantepec Railroad from coal engines to oil engines was about £118. If the capital charges on £118 were added to the capital charges of the cost of the coal-burning apparatus, it was apparent that the capital costs of the locomotive were considerably increased, and in computing the economies that were supposed to result from the use of oil-locomotives, it was very seldom that any allowance was made for the interest on that increased amount of capital expenditure. The design of the fire-box arrangement for the engines on the Tehuantepec Railroad was more or less different from what was usually done in America. There were no dampers, lack of which had always in America caused considerable trouble to the fire-boxes by reason of cold air being driven into the fire-box after the burner was shut off. If the drawing showing the design of the fire-box were studied, it would be seen that a brick wall was shown at the fire-door end, and an air-space was shown between the fire-brick wall and the fire-box. What usually happened in those cases was that cold air went up through that space, then passed across the top of the fire-box, and right into the top row of tubes, so that a cold current of air was obtained right on top of the oil flame. That did not seem to be a very good thing for the fire-box. Where there was a large amount of fire-brick and the brick-pan was moved up from the fire-box, the effective heating surface of the fire-box was considerably reduced. If the pan had been dropped down and fastened to the mud ring, a larger heating surface would have been obtained. So far as he had been able to ascertain, oil-fuel considerably affected stay-bolts, and it had been the usual practice in America to taper the stay-bolt so that if the head was burnt off the sheet would not drop. The stay-bolt thread being tapered held the sheet up.

The statement was made in the Paper that the burner was made by the Company; and that it was an inverted "Best" burner. This hardly appeared to be an accurate description, as in the Tehuantepec burner the oil was fed through a narrow slot instead of through a spoon as in the "Best" burner, and the present Tehuantepec burner appeared to be very similar to the burner designed by The Baldwin Locomotive Works and described in Mr. Greaven's Paper.* This burner has been applied to several hundred locomotives, and so far as he knew it had done very good service. Some very interesting figures had been published by Mr. Stillman of the Southern Pacific Railroad, which had more

* Proceedings, I.Mech.E., 1906, Part 2, page 265.

(Mr. F. N. Poignand.)

oil-burning locomotives running than any railroad in the United States. Evaporative tests of about 745 locomotives showed that the evaporative power while running was 152 gallons, or 3·62 barrels was equal to that of 2,000 lb. of coal, the oil having a heating value of approximately 18·500 B.Th.U. per lb., and the coal 13·350 B.Th.U.

In one series of tests with a Mallet locomotive the mean horse-power was 2,057; the water evaporated per square foot of heating surface per hour was 6·39 lb.; the oil used per square foot of heating surface per hour was 0·518; the oil per i.h.p. was 1·61; the equivalent evaporation per lb. of oil was 15·04; and the weight of the train was 1,056 tons. With regard to the question of combustion in an oil-burning fire-box, it was undoubtedly the fact that in the fire-box used on the Tehuantepec Railroad the combustion was not complete, otherwise it would not be necessary to use so much sand. Sand was always thrown into the fire-box to clean the flues of soot which was deposited owing to the incomplete combustion. Unless there was sufficient fire-box volume, although the oil might be atomized it was not completely burnt, and unless the gas was completely burnt and entered the tubes as products of combustion, there was very little chance of the gases completing their combustion in the tubes, due to the lower temperature of the tubes. Unless the fire-box temperature was high, the combustion could not be complete. Professor Grey of California University has ascertained that with the Southern Pacific oil-burning locomotives the temperature in fire-boxes ranged from 2,500° F. to 2,750° F.

Mr. R. GODFREY ASTON wrote, in reply to the remarks of Mr. T. O. Mein, that his surmise was quite correct that, when using Mexican oil in the locomotives, complete combustion did not take place, as shown by the deposits of carbon or cokelike substances which were deposited, or which formed in the fire-box when using this oil. When the author left Mexico at the end of December 1911, they had by means of different adjustments, such as raising the burner and admitting a little more air to the fire-box between the two pans, considerably reduced in size these pieces of carbon or cokelike substances, although they had not managed completely to stop their forming. With Texas oil with a Beaumé gravity between 20° and 30°, they obtained a very efficient atomization and combustion with their present burner, no smoke being made except when sanding, or carbon deposits forming. But owing to the low gravity and high percentage of asphalt in this Mexican oil, it took considerably more pulverizing in order to gain complete atomization and combustion, and with this object he recommended various alterations to the burner, etc.; but as they had not been made before he left Mexico, he could not say what the effect had been, and whether the evil had altogether been remedied.

He had known for many years that the Great Eastern Railway were users of liquid fuel, and that they had attained some very efficient results with the "Holden" system, with which he regretted to say he had never come into contact. Mr. Mein's remark that the longest run made by an express engine was 532 miles without the fire being cleaned was very interesting, but he did not mention what class of oil-fuel was used, whether pure crude, a residuum, or a manufactured fuel-oil.

When burning Mexican oil, it was necessary to clean out the fire-boxes of the Tehuantepec engines after every trip across the Isthmus, 304 kilometres (189 miles), but with Texas oil this was never necessary, there being no coke deposits, or unburnt oil in the fire-box.

With regard to Mr. F. N. Poignand's remarks, which were equally interesting, especially as he had been engaged on the design of oil-burning locomotives in America, he noted the remarks as to the cost of oil and coal as fuel on the Tehuantepec National Railroad in 1906, and the cost per engine-mile as the fuel-oil worked out during the period covered by the Paper. As the author has now resigned his position with the Tehuantepec National Railroad, he regretted that he had no data at hand on this subject; during the five years he was with this Company they had no coal-burning engines; however, owing to the great decrease in the oil production of Texas during the last few years, the price per barrel

(Mr. R. Godfrey Aston.)
of this oil has considerably increased. But as the Mexican fields were now producing an almost unlimited amount, the price per barrel was decreasing, so that from August or September 1911 the cost per engine-mile of the Tehuantepec National Railroad should decrease in proportion, as they were in November purchasing Mexican residuum (fuel-oil) for $1·50 Mex. (3*s.*) per barrel of 42 U.S. gallons, and the price might go even lower still.

As regards the oil-tank, stated in the Paper to be near the round-house, Mr. Poignand was quite correct in saying that the insurance company would not allow such a tank to be put alongside it. The tank in question was some 100 yards distant from it, and the statement that it was "near the round-house" was vague, and only meant to show its place in relation to the storage-tanks.

He presumed the remarks as to the cost of £118 in converting a coal-burning to an oil-burning engine were taken from Mr. L. Greaven's Paper. But as they now made their own burners and connections, the cost fell very much below this. No road or main-line engines have been converted since the author's connection with the Company, but he would say the cost would not be over £75 at the present time.

With regard to the design of the fire-box arrangement, which, as Mr. Poignand remarked, was more or less different from the usual design of oil-burning fire-boxes in America, it was at first rather a surprise to the author, especially as there were no dampers, and as it seemed so easy a matter for cold air to get in above the flame, or when the burner was shut down. He had personally drawn attention to this many times and had made recommendations in order to remove this risk, but without success; it was claimed that no improvement could be made, as there was no appreciable effect on the flues, although what little trouble they had with leaky flues was more so towards the top rows. The pan arrangement could be very much improved upon, for much heating surface is lost at the front end. But in order to utilize this heating surface, the pan would have to be lowered at the back and front and raised in the middle, in order to clear the axle underneath, so that this axle accounted for the present design. All stay-bolts were hollow and not tapered, and the Tehuantepec Railroad had not experienced any trouble with burnt-off heads.

In describing the burner as used by the Tehuantepec National Railroad as an inverted "Best" burner, he compared the two, in that the "Best" burner delivered the oil below the steam, and in the Tehuantepec burner the oil was delivered above the steam; but as Mr. Poignand said, the Tehuantepec burner was really more like the well-known "Baldwin" burner, and with which all their locomotives were fitted when delivered by that Company. But as they attained the same or even better results with their own type of burner, besides making it in their own shops, the maintenance of the burner and burner equipment was considerably cheaper.

With regard to sanding, this was a matter which was at the discretion of the engineer or driver, but as all the firemen were Mexicans, and not at all reliable, drivers or engineers (Americans) usually insisted that the flues should be sanded or cleaned frequently, otherwise it would be impossible to get the heavy trains over the heavy grades. The general type of firemen in Mexico were negligent and careless in firing, unless continually looked after by the engineer or driver.