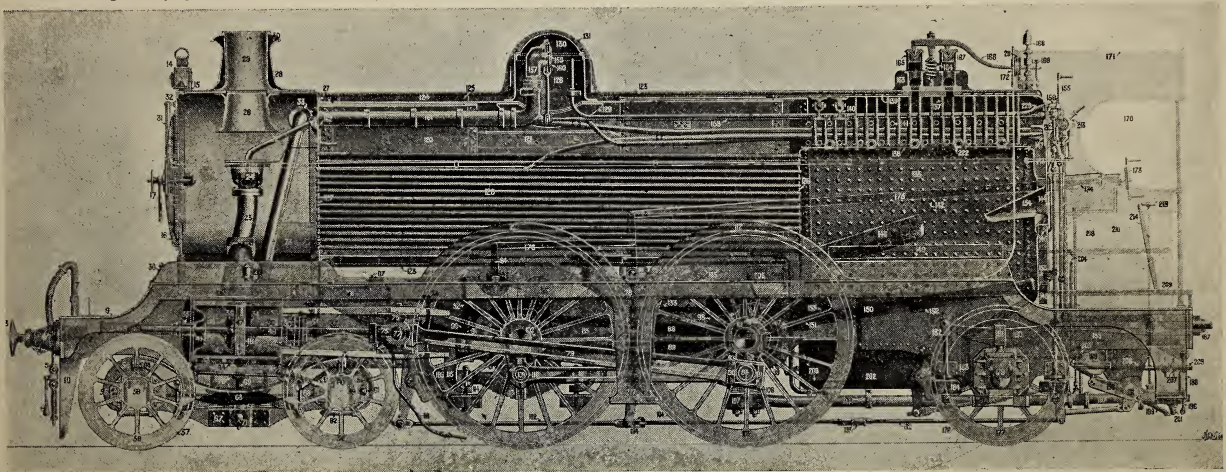
THE LOCOMOTIVE HANDBOOK

LONDON:
THE LOCOMOTIVE PUBLISHING CO., Ltd.
3, AMEN CORNER, E.C.

BRITISH ATLANTIC TYPE LOCOMOTIVE.

Designed by J. G. ROBINSON, Esq., M. Inst. C.E., M. Inst. Mech. Eng., *Chief Mechanical Engineer*, *Great Central Ry.*



REFERENCE TO NAMES OF PARTS.

1. Buffer Beam.
2. Draw Bar.
3. Draw Bar Hook.
4. Draw Bar Rubbers.
5. Screw Coupling.
6. Screw Coupling Ball.
7. Vacuum Brake Pipe.
8. Vacuum Brake Hose.
9. Front End Plate.
10. Guard Iron.
11. Buffer Socket.
12. Buffer Rod.

58. Bogie Wheel Axle.
59. Bogie Wheel Axle Box.
60. Bogie Wheel Axle Brass.
61. Bogie Horn Plate.
62. Bogie Horn Plate Stay.
63. Bogie Equalizing Beam.
64. Bogie Equalizing Beam Bearing.
65. Bogie Spring.
66. Bogie Spring Band.
67. Bogie Spring Band Bracket.
68. Bogie Spring Hanger.
69. Bogie Pin.

113. Coupled Wheels Spring.
114. Coupled Wheels Spring Hanger.
115. Coupled Wheels Spring Hanger Bracket.
116. Sand Box.
117. Sand Box Filling Lid.
118. Sand Pipe.
119. Sand Valve.
120. Boiler Shell.
121. Boiler Longitudinal Seam.
122. Boiler Circumferential Seam.
123. Boiler Cleading Plate.

169. Whistle Valve.
170. Cab.
171. Cab Roof.
172. Cab Window.
173. Reversing Wheel.
174. Reversing Screw.
175. Reversing Rod.
176. Reversing Rod (Intermediate).
177. Trailing Wheel.
178. Trailing Wheel Tyre.
179. Trailing Wheel Axle Box.
180. Trailing Wheel Spring.

13. Buffer Head.
14. Lamp.
15. Lamp Iron.
16. Smoke Box Door.
17. Smoke Box Door Handle.
18. Smoke Box Door Hinge.
19. Smoke Box Door Baffle.
20. Smoke Box Spark Arrester.
21. Blower.
22. Blower Pipe.
23. Blast Pipe.
24. Blast Pipe Nozzle.
25. Blast Pipe Y Joint.
26. Petticoat Pipe.
27. Smoke Box Ring.
28. Chimney.
29. Chimney Liner.
30. Chimney Cap.
31. Hand Rail.
32. Hand Rail Pillar.
33. Steam Pipe T Piece.
34. Slide Valve.
35. Slide Valve Tail Rod Gland.
36. Slide Valve Spindle.
37. Slide Valve Intermediate Spindle
38. Flap Plate.
39. Steam Port.
40. Cylinder.
41. Cylinder Front Cover.
42. Cylinder Back End.
43. Cylinder Lagging.
44. Cylinder Cleading.
45. Cylinder Cocks.
46. Cylinder Cock Gear.
47. Piston.
48. Piston Rings.
49. Piston Rod.
50. Piston Rod Metallic Packing.
51. Piston Rod Gland.
52. Piston Tail Rod.
53. Piston Tail Rod Casing.
54. Bogie Frame.
55. Bogie Frame Stay (Cross)
56. Bogie Wheel.
57. Bogie Wheel Tyre.
70. Bogie Pin Casting.
71. Bogie Spring Pin.
72. Slide Bar.
73. Smoke Box Liner.
74. Motion Plate.
75. Cross Head.
76. Cross Head Shoes.
77. Cross Head Pin.
78. Platform Support.
79. Connecting Rod.
80. Connecting Rod Big End.
81. Connecting Rod Big End Brass.
82. Connecting Rod Big End Oil Box
83. Connecting Rod Big End Cotter.
84. Crank Pin.
85. Inside Frame Plate.
86. Eccentric Sheave.
87. Eccentric Strap.
88. Eccentric Rod (Fore Gear).
89. Eccentric Rod (Back Gear).
90. Expansion Link.
91. Expansion Link Block.
92. Suspension Link.
93. Weigh Shaft.
94. Weigh Shaft Lever.
95. Weigh Shaft Lever Balance Weight.
96. Weigh Shaft Bearing.
97. Driving Axle.
98. Driving Horns.
99. Driving Horn Stay.
100. Driving Axle Box.
101. Driving Axle Box Brass.
102. Driving Axle Box Wedge.
103. Driving Wheel.
104. Driving Wheel Tyre.
105. Driving Wheel Balance Weight.
106. Driving Wheel Springs.
107. Driving Wheel Springs Rubber Box.
108. Side Rod.
109. Side Rod Pin.
110. Side Rod Bush.
111. Side Rod Oil Box.
112. Coupled Wheel Splashers.
124. Boiler Lagging.
125. Boiler Cleading Band.
126. Boiler Tubes.
127. Smoke Box Tube Plate.
128. Dome.
129. Dome Ring.
130. Dome Cover.
131. Dome Casing.
132. Internal Delivery Pipe.
133. Blow-Off Pipe.
134. Blow-Off Cock.
135. Fire Box.
136. Fire Box Tube Plate.
137. Fire Box Crown Stay Bolts.
138. Fire Box Crown.
139. Fire Box Wrapper Plate.
140. Fire Box Crown Sling Stays.
141. Fire Box Cross Stays.
142. Fire Box Side Stays.
143. Fire Box Water Space.
144. Fire Door.
145. Fire Door Ring.
146. Brick Arch.
147. Gusset Stay.
148. Foundation Ring.
149. Expansion Bracket.
150. Fire Bar.
151. Fire Bar Bearer.
152. Fire Bar Bearer Bracket.
153. Mud Door.
154. Deflector Plate.
155. Regulator Lever.
156. Regulator Lever Quadrant.
157. Regulator Head.
158. Regulator Rod.
159. Regulator Slide Valve.
160. Regulator Auxiliary Valve.
161. Steam Pipe.
162. Steam Pipe Joint.
163. Safety Valve Casing.
164. Safety Valve Spring.
165. Safety Valve Columns (four).
166. Safety Valve Lever.
167. Safety Valve (four).
168. Whistles (two).
181. Trailing Wheel Spring Band.
182. Trailing Wheel Spring Hanger.
183. Trailing Wheel Spring Hanger Bracket.
184. Trailing Wheel Spring Rubbers.
185. Drag Plate Casting.
186. Tender Coupling.
187. Tender Buffers.
188. Safety Chain.
189. Steam Brake Cylinder.
190. Steam Brake Lever.
191. Steam Brake Lever Shaft.
192. Brake Pull Rods.
193. Brake Rod Adjusting Nut.
194. Brake Beam.
195. Brake Block.
196. Exhaust Steam Injector.
197. Exhaust Steam Pipe to do.
198. Exhaust Steam Grease Separator
199. Exhaust Steam Injector Overflow
200. Live Steam Injector, Steam Pipe.
201. Live Steam Injector, Overflow.
202. Ash Pan.
203. Ash Pan Framing.
204. Damper Rod.
205. Damper Gear.
206. Feed Water Pipe.
207. Feed Water Pipe Coupling.
208. Feed Water Hose.
209. Foot Board.
210. Locker.
211. Steam Gauge.
212. Water Gauge.
213. Vacuum Brake Valve.
214. Cylinder Cock Lever.
215. Train Pipe.
216. Outside Angle Iron.
217. Steps.
218. Number Plate.
219. Water Regulator to Injector.
220. Steam Pipe to Injector.
221. Cylinder Lubricator.
222. Wash-out Plugs.

NOTE.—*An enlargement, the original of the above reproduction, also a Companion Chart of a Caledonian Railway Six-coupled Express Locomotive, can be procured from all Booksellers and Newsagents, or ordered from the Locomotive Publishing Company, Ltd., 3, Amen Corner, London, E.C., price 1/.*

THE

Locomotive = = Handbook

OF

Useful Memoranda and Data.

1907.

SECOND EDITION.

London:

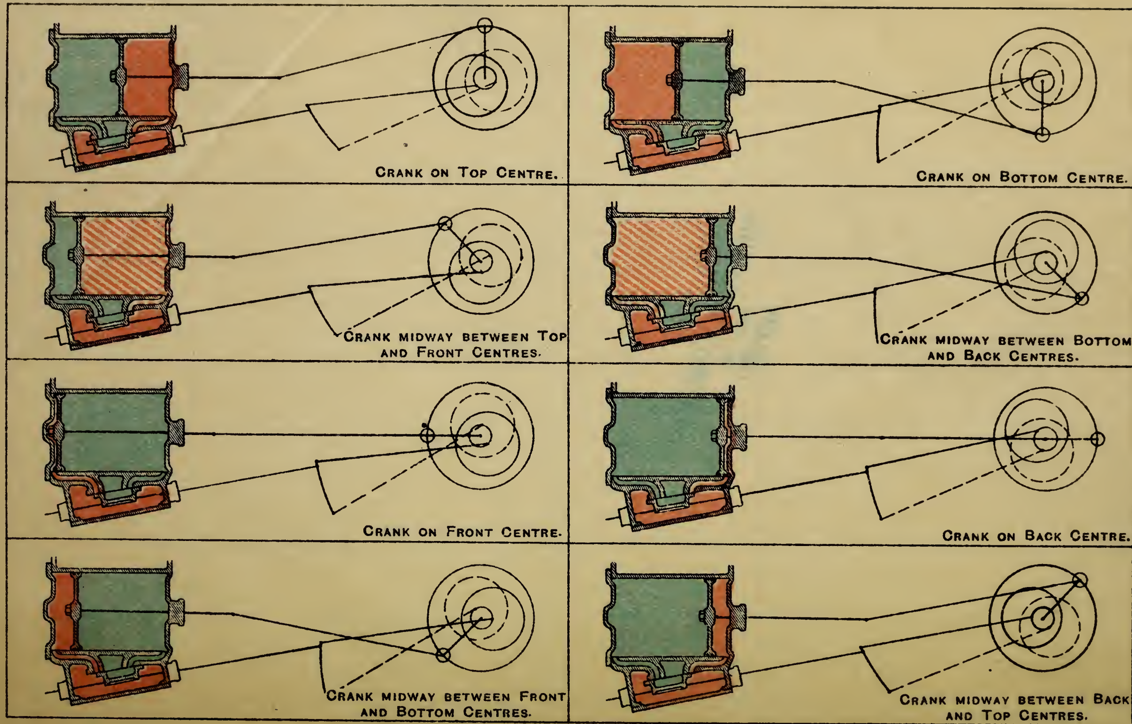
THE LOCOMOTIVE PUBLISHING COMPANY, Ltd.

3, AMEN CORNER, PATERNOSTER ROW, E.C.

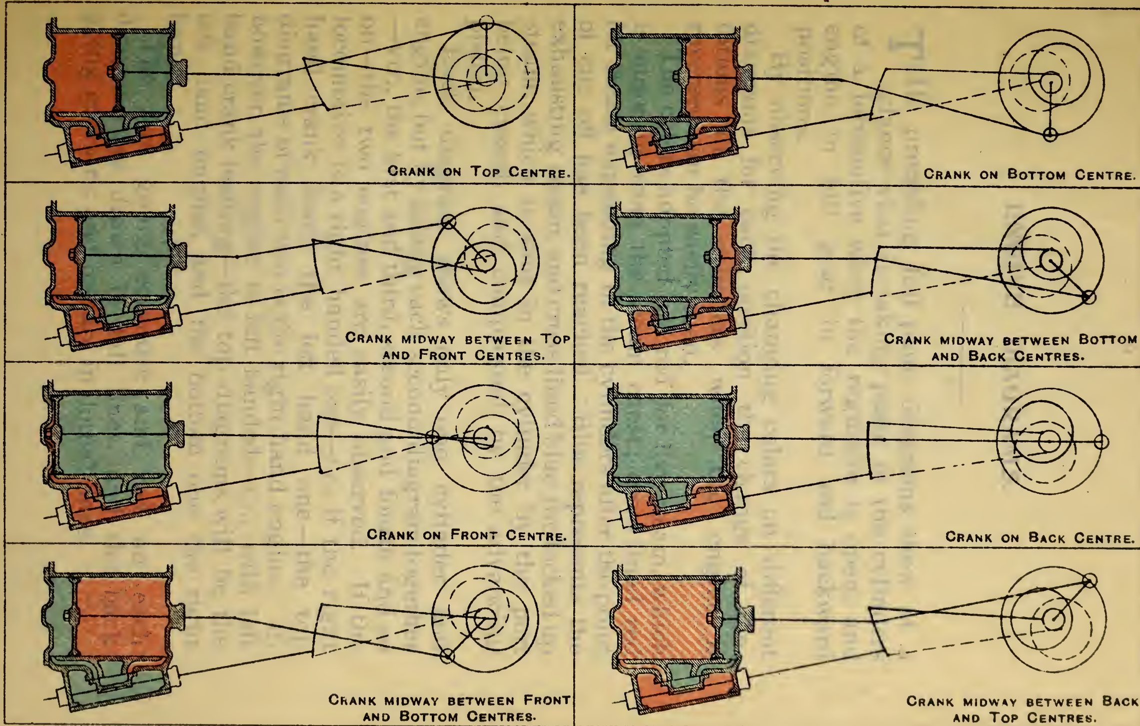
Calcutta : "The Indian Railway Gazette," 10, *Dacre's Lane.*
New York : The Derry Collard Co., 109, *Liberty Street.*

CONTENTS.

ENGINE DIAGRAMS—SERIES No. 1.



FORE GEAR.


CRANK ON TOP CENTRE.
CRANK ON BOTTOM CENTRE.
CRANK MIDWAY BETWEEN TOP AND FRONT CENTRES.
CRANK MIDWAY BETWEEN BOTTOM AND BACK CENTRES.
CRANK ON FRONT CENTRE.
CRANK ON BACK CENTRE.
CRANK MIDWAY BETWEEN FRONT AND BOTTOM CENTRES.
CRANK MIDWAY BETWEEN BACK AND TOP CENTRES.

BACK GEAR.

ENGINE DIAGRAMS.

THE preceding full page diagrams show at a glance what is taking place in the cylinders of a locomotive when the regulator is open, and engine in full gear in forward and backward positions.

By observing the changing colors on different diagrams for each position the change of conditions in the cylinders when the engine is reversed can be easily seen.

The colors adopted are red for live steam, which is entering from the steam chest; cross lined red for steam expanding in the cylinders after the point of cut off has been reached. Blue represents the exhausting steam, and cross lined blue the locked up steam, which is shut in the cylinder by the port being closed, and compressed by the advancing piston.

Each diagram shows only one cylinder and engine, but by taking each second diagram together —viz., the first and third, second and fourth and so on—the two engines are easily observed. If the locomotive is a right handed one—*i.e.*, if the right hand crank leads the left hand one—the top diagrams of each two is the right hand engine. If, however, the engine is left handed—*i.e.*; with left hand crank leading—the top diagrams will be the left hand engine, and the bottom one the right hand.

The fore going eccentric and rod on each diagram are drawn in full lines, and the back going eccentric and rod are in dotted lines.

SPEED.

SECONDS PER MILE IN MILES PER HOUR.

Seconds per Mile.	Miles per Hour.	Seconds per Mile.	Miles per Hour.	Seconds per Mile.	Miles per Hour.
24	150	47	76.6	70	51.4
25	144	48	75	71	50.7
26	138.5	49	73·4	72	50
27	133.3	50	72	73	49.3
28	128.5	51	70.6	74	48.6
29	124.1	52	69.2	75	48
30	120	53	67.9	76	47.3
31	116.1	54	66.7	77	46.7
32	112.5	55	65.5	78	46.1
33	109.1	56	64.3	79	45.6
34	105.9	57	63.1	80	45
35	102.8	58	62.1	81	44.4
36	100	59	61	82	43.9
37	97.3	60	60	83	43.3
38	94.7	61	59	84	42.8
39	92.3	62	58.1	85	42.3
40	90	63	57.1	86	41.8
41	87.8	64	56.2	87	41.4
42	85.7	65	55.3	88	40.9
43	83.7	66	54.5	89	40.4
44	81.8	67	53.7	90	40
45	80	68	52.9	91	39.5
46	78.3	69	52.1	92	39.1

TEMPERATURE NOTES.

Approximate Temperature of a Fire as indicated by its appearance.

Red, just showing	about	1000° F.
,, dull	,,	1300° F.
,, bright	,,	1800° F.
Orange, deep	,,	2000° F.
,, bright	,,	2200° F.
Yellow	,,	2400° F.
White	,,	2600° F.
Intense White Heat, as of a furnace	,,	2800° F.

Approximate Temperature of a Journal as indicated by its appearance when heated.

Faint Yellow	at	430° F.
Straw	,,	450° F.
Full Yellow	,,	470° F.
Brown Yellow	,,	490° F.
Brown, turning to Purple ..	,,	510° F.
Purple	,,	530° F.
Bright Blue	,,	550° F.
Full Blue	,,	560° F.
Dark Blue	,,	600° F.

"White metal" melts at 450° F.

Brass melts at 1,650° F.

Approximate Temperature of Steam as shown by the Gauge on a Locomotive up to 200 lbs. per sq. in.

50 lbs. per sq. in. ..	298° F.	150 lbs. per sq. in. ..	366° F.
100 ,, ,, ..	338° F.	160 ,, ,, ..	370° F.
110 ,, ,, ..	344° F.	170 ,, ,, ..	375° F.
120 ,, ,, ..	350° F.	180 ,, ,, ..	380° F.
130 ,, ,, ..	356° F.	190 ,, ,, ..	384° F.
140 ,, ,, ..	360° F.	200 ,, ,, ..	388° F.

Water freezes and becomes ice at 32° F., it reaches its maximum density or contracts to its minimum compass at about 39° F., hence ice always floats and pipes and chambers, such as sight feed lubricators, reservoirs, etc., are liable to be fractured or burst when their contents become frozen.

An imperial gallon of fresh water weighs 10 lbs. and a cubic foot contains $6\frac{1}{4}$ gallons.

A cubic foot of fresh water at	32.0° F. weighs	62.418 lbs.
,, ,, ,,	39.1° F. ,,	62.425 ,,
,, ,, ,,	62.0° F. ,,	62.355 ,,
,, ,, ,,	212.0° F. ,,	59.760 ,,

ECONOMY IN FUEL

Secured by Feeding a Boiler with Heated Water.

Temperature of cold water assumed to be 60° F. and the boiler pressure from 140–200 lbs. per sq. in.

If heated to—	The approximate gain in fuel will be—
100° F.	Over 3 per cent.
150° F.	,, 8 ,,
200° F.	,, 12 ,,
250° F. (by the aid of exhaust injector)	,, 16 ,,

THE VALUE OF FUEL.

The chief components of any fuel useful for the generation of heat are carbon and hydrogen, and as these when effectually consumed with the requisite proportion of oxygen give off known quantities of heat, it is easy to ascertain the heating value of any fuel from its chemical analysis.

For the combustion of 1 lb. of carbon, 2.66 lbs. of oxygen are required, and as atmospheric air contains but 23 per cent. of the latter, it follows that nearly 12 lbs. of air are required for the consumption of 1 lb. of carbon.

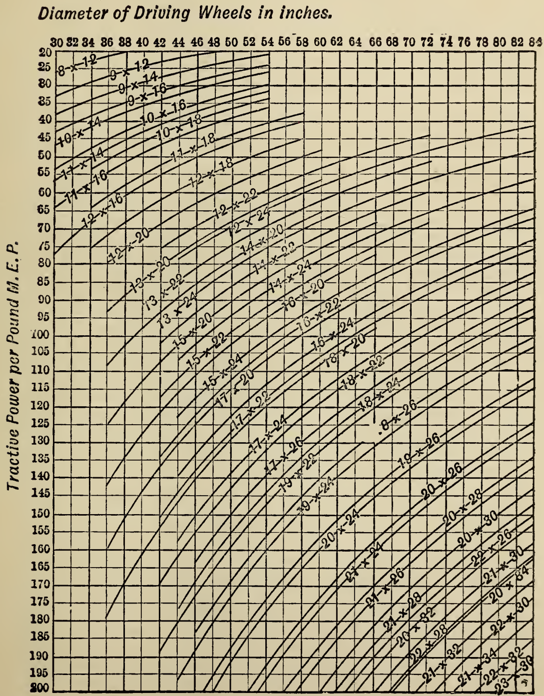
1 lb. of hydrogen requires 8 lbs. of oxygen, or, approximately, 35 lbs. of air. In actual practice twice this is usually allowed to compensate for the fact that so much of the air admitted through the firegrate does not get intimately incorporated with the fuel.

The following table gives approximate values for the chief locomotive fuels. As the actual efficiency of every sample of coal will vary, only the "general" figures are given, which is sufficient for purposes of comparison.

Grade of Coal. Average Samples.	Per cent. of Carbon.	Per cent. of Hydrogen.	Per cent. of Sulphur, Ash, &c.	Approx. Evaporation. Theoretical lbs. of water per lb. of fuel.	Actual on a Locomotive lbs.
Welsh ..	92	3.5	4.5	14	9
Yorkshire ..	79	5.0	16.0	13	8
Lancashire ..	76	5.0	19.0	12½	7½
Scotch ..	80	5.0	15.0	13	8
Pennsylvania	90	2.5	7.5	13	8
India ..	60	3.0	—	12	7
Australia ..	68	2.5	—	10	6½
S. Africa ..	50	3.0	—	8	5

DIAGRAM OF TRACTIVE POWER OF LOCOMOTIVES.

Tractive Power of Locomotives per Pound of Mean Effective Pressure.



From the "LOCOMOTIVE ENGINEER'S POCKET BOOK," *published by The Locomotive Publishing Co., Ltd., price One Shilling.*

LOCOMOTIVE ENGINE DRIVING.

FEW trades or professions can be learned by simply reading treatises on them—least of all, perhaps, engine driving. This is evident from the scarcity of literature which deals directly with the subject. There are certain well-known books which deal with the art in some way, but on the whole locomotive engine driving, from a driver's point of view, has not inspired many pens, not because it is not sufficiently interesting, but owing to the great difficulty of conveying by writing just what a driver wants to know.

There is no difficulty about describing the mechanical details of an engine and giving valuable information on the best known methods of dealing with them. For example, this is admirably done in "The Locomotive of To-day," but the actual handling of the engine on the road is quite a different matter. Ask any driver how he can judge where to shut off steam and where to apply the brake so as to stop at the right place at any given station under different conditions of weather, load, etc. In all probability he will look at you with a bewildered air and reply, "I don't know," notwithstanding the fact that he has done it himself for twenty or more years without a single failure. He will brighten up at once, however, when he thinks of an alternative, and invites you to go and see for yourself how he does it. He cannot tell you, but he can show you. Unless you have had considerable experience on the footplate, you will be just as wise after the demonstration as you were before it.

Few people think how lonely a driver must be when on the road. He stands for hours looking through the window of the cab while signal after signal passes across his vision, and he must, without fail, detect one out of hundreds which is only different in colour from all the rest. Should he not obey that one the probability is that in a very short time the whole country will be apprised of his mistake by the proclamation of newspaper bills.

Seldom does a word pass between the driver and fireman on the road, unless something unusual happens, and even then it is only what is necessary that is said. Apart from the noise in the cab, which makes conversation difficult, each has his duties to attend to, and these take up his whole attention. The fireman is so busy attending to the fire, water and lubrication that he has no time for anything else except to look out for signals as much as he can. Any neglect on the part of the fireman or an error in judgment in firing heavy expresses lands the driver in difficulties for steam supply. The driver's anxiety on this score is well seen by the frequency with which he steals a glance at the water and pressure gauges. In fact he hardly ever takes his eyes off the lookout window for any other purpose.

A driver actually feels as if he were a part of the complete machine. He can almost instantly detect anything unusual, He can smell a hot bearing and feel the breakage or displacement of any part, even if it should not be so serious as to cause him to stop. When anything of the kind does unfortunately happen, the driver's anxiety is seriously increased. His business is to land his train safely, and if possible up to time. The loss of one minute is recorded against him, and he must be prepared to account for it. Any trivial excuse will not be accepted as justifying loss of time, and he knows it. On that account slowing down or stopping are the very last things he thinks about, and after all the responsibility rests with him; he has no time for consultation, even if a consultant were available. He must act at once.

Enginemen will generally face any kinds of weather without concern, with one exception. Ask any driver what tries his nerves most, and without hesitation he will answer in monosyllable—"Fog."

During fog he has scarcely anything to guide him except ghostly shadows of signals, and these he must sometimes count as he goes along. If he loses his reckoning he is in great suspense till he passes some familiar landmark, such as a bridge, cutting, station, or something which he can recognise from sound. Sometimes for hours he has to stand with his face projecting past the side of the cab, straining his eyes till they ache, in the vain attempt to pierce the impenetrable fog. Under such conditions is it surprising if he utters a word of thankfulness on reaching the end of his journey in safety.

There is absolutely nothing written which will help a driver to learn the road or to distinguish signals. The colours, position of arms, and a few more points are well and clearly defined. All signalling is carried out on certain general principles, but the peculiarities of different junctions and crossings cause these general methods to be modified so frequently that few standing rules can be framed for precise guidance on all occasions.

Locking and interlocking of points and signals are so thoroughly carried out now that the risk of mistake by a signalman has been reduced to a minimum. In fact, about the only mistake he can now make is that of allowing one train to follow another before the section is clear.

On the other hand the driver has so far received neither help nor check to his reading of the signals, so that an overlook or mistake on his part is quite as possible now as it was 30 years ago. Many attempts have been made to invent a reliable mechanical system by means of which a train could be stopped in the case of a driver passing a signal at danger. None of these has proved so successful as to induce railway companies to adopt them.

In order to become a first class driver a man must almost live on the engine till he becomes like a part of it, and he must run over the line till he knows it so well that he could tell where he is and at what speed he is running at any moment, even if blindfolded. This is actually the condition in which some men are to-day. They know every yard of the road, with signals, loops, junctions, and all the rest, between Carlisle and London, a distance of some 300 miles.

Unimpaired faculties, good sound robust constitution, steadiness of habits along with patience and perseverance, are all essential for the making of such an engine driver. And with it all the driver is a very modest man. He has no gold braid, no glittering brass buttons, and none of the objectionable airs which the wearers of those fine clothes so often possess.

The guard can always be seen fussing about as if the whole train, driver and all, belonged to him He walks up to the driver, asking his name with quite an authoritative air. "Brown" or "Jones," as the case may be, is all the answer, unless it should be some out-of-the-way name, when the driver spells it. It is the guard's duty to tell the driver what load he has on, and should it exceed the stipulated amount he may ask, "Can you take 'em alone?" "Try," comes the laconic reply, and that is all there is about it.

The passengers see the guard, and no doubt admire him sufficiently, but while they settle themselves comfortably in a corner behind a newspaper, with never a doubt about being landed safely at their destination, they seldom think of the two pairs of eyes at the front end upon which everything depends.

FIRING LOCOMOTIVES AND CARE OF THE BOILERS.

TO get good results from any fuel it is advisable to become acquainted with the elementary principles of combustion and fire in accordance with them. The heating properties of different coal are given in the table on page 12, and from this a comparison may be made as to the value of that in use on any particular railway. Roughly, coal of ordinary quality requires some 20-lb. of atmospheric air per lb. to ensure good combustion, and on the proper admission and admixture of this with the combustible elements of the fuel depend the results obtained. Naturally with different grades of coal the methods of firing must be varied to suit; with "hard" steam coal (Yorkshire, Durham, etc.) a thin fire replenished at frequent intervals with small charges will ensure most steam, whilst with "soft" coal (Welsh) a heavy thick fire can be built up and relied upon for satisfactory generating power.

In a thick fire of hard coal the air drawn through the grate is first brought into contact with that portion of the coal lying on the bars, with the consequence that this lower layer burns briskly—giving off heat which is partially absorbed by the upper layers of "green" coal, the lighter and volatile constituents of which are distilled off, producing smoke, a dull fire, and little steam. With poor quality coal the formation of clinker is considerably assisted by heavy firing, and it is desirable to run with as light a fire as possible when using inferior fuel.

Failure in maintaining steam may be attributed to the engine being overworked, owing to the weight or booked speed of the train being in excess of the engine's capabilities, any difficulty in this direction, however, should, if possible, be anticipated before commencing the trip. The tubes should be properly cleaned so as to get all the possible heating effect from them, and the fire should be clear and bright without clinker, to obstruct the air passing through the firebars and deaden the fire. The boiler should be well filled with water, and the steam pressure raised to just below blowing-off point before the starting time of the train, so that all the energy possible is ready for the work.

When the engine pulls out of the station the fire-door should not be opened nor the injectors worked until the train is moving fairly fast, and the expansion gear is notched up into approximately its running position.

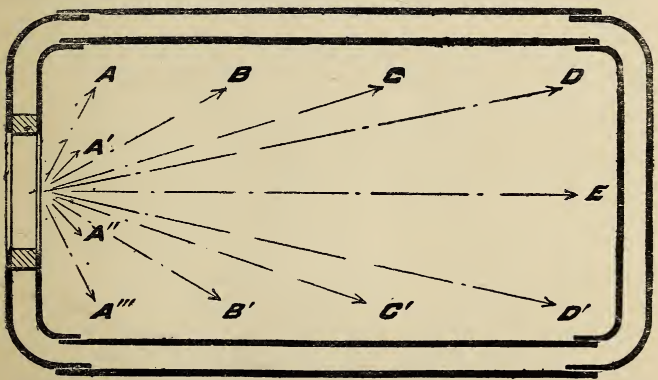


FIG. 1.

If necessary a little more fire may be put on then, from four to six shovelsful, the coal being broken up to about the size of cobbles and well spread over the bars, with a larger proportion at the sides and corners, whence it will gradually shake down into the centre of the firegrate. The coal being broken up will more readily ignite and give off heat than if put on in large lumps.

Whilst on the run the coal should be thrown in at regular intervals with due regard to the road, keeping the fire thin about the centre of the grate, and thicker along the sides and at the back; a good plan is to make a complete circuit of the firebox in from three to four applications. The diagram (Fig. 1) illustrates this—starting with the back of the grate, two shovelsful would be thrown into the corners A A''', at the next opening of the door two to B B', then C C', D D' and E, winding up with A' A''; the round of a large grate being performed with more shovelsful per firing than a smaller one.

Want of Steam may be due to carelessness on the part of the fireman by firing too heavy or putting large lumps of coal on an already nearly dead fire, so that it takes some time to ignite, or by allowing clinker to accumulate upon the bars. The formation of this latter may sometimes be traced to the ash-pan being nearly full of cinders, which obstruct the passage of air.

As already mentioned, coal, if put on in excessive quantities, will not burn at once, because when first thrown into the firebox it absorbs a large quantity of heat, swells, cracks and gives off gas before igniting. If the fire is not hot enough to raise the coal to this point rapidly it will continue to give off gas for some time, with the result of imperfect combustion, smoke; this latter will cause soot to be deposited in the tubes, which in turn will retard the passage of the heated gases generated by the fully ignited fuel and absorb some of the heat. On the other hand, dulness in steaming may be due to air inlets in the smokebox, through bad joints, etc., partially destroying the vacuum there, and detracting from the draft upon the fire. Another cause may be in the blast pipe and chimney not being perfectly true or central with each other, so that the full effect of their correct combination is lost. This is indicated by the smoke and steam striking on one side of the chimney, and can be accurately proved in the shed by wiping the interior of the base of the chimney round with a piece of oily waste and noting the appearance after the exhaust of a beat or two has passed through. These defects cannot be rectified by the driver, but should be at once booked when detected, so that they may be put right by the shed staff, as a good "steamer" will never be secured until they are. To counteract the deficiencies in steam production as much as possible the feed must be "nursed," and only applied at favourable times, and the driver must take every opportunity to economise in consumption of steam on down grades and other points where power can be saved.

If all precautions are taken, and it is found impossible to keep up the pressure and water level, then it may be assumed that the load is too great for the engine with its small reservoir of steam to draw from. This trouble is one that will not be so common in the future as it has been in the past, the tendency being to build the boilers of new locomotives of a size more in accord with the power they are expected to develop.

It is a common expedient, if an engine will not steam well to brick up the smokebox and so decrease its cubical capacity, the blast then has a much sharper and "biting" action on the fire, increasing the rate of combustion; if such a decrease in capacity, however, be carried too far, small pieces of unconsumed coal from the firebox will be drawn through the tubes and thrown from the chimney, thus wasting fuel as well as endangering property adjacent to the railway from fires caused by the "sparks." The continual lifting of the fire by a sharp "cutting" blast will wear away the plates of the firebox above the level of the surface of the fire, and the tubes also will be badly scored, especially if of copper or brass.

It should be the desire of every engineman to run with as soft a blast as is consistent with good steaming properties, anything sharper than necessary for this whether produced by reducing the size of the smokebox or contracting the blast pipe outlet is to be deprecated. The latter expedient, the reduction of the blast outlet will seriously affect the coal bill as it increases the back pressure, and, therefore, the amount of work the engine will have to do ; steam will be wasted in simply overcoming the resistance to escape which that imprisoned in the cylinders encounters after it has done its work.

The firegrate should receive careful attention on every possible occasion, especially on shed days ; any burnt or bent bars should be removed and new ones put in to replace them. All the air spaces between the firebars should be as uniform as possible and not too large, as in this latter case the ashes that fall through into the ashpan will be large and represent unconsumed fuel. The sides, front and back ends of the grate should be looked to, and the bars at these places fitted in "snugly" to prevent as much as possible the access of large volumes of cold air there ; the firebox plates, owing to the presence of water on the other side of them, are much below the temperature at which coal is ignited, and as all the air that enters must be raised to the proper heat before it assists in combustion, it follows that air should be prevented from impinging upon the side plates before it has chemically combined with the coal and fire, and proper combustion has taken place. Some engineers carry this idea to its logical conclusion, and make the sides and both ends completely air-tight by fixing dead plates round the edge of the bars, rigorously excluding all air from entering there.

The proper height for the bars is another important matter which is often slighted, a little difference in this will often affect the steaming powers of an engine considerably. It is generally conceded that the rear of the grate should be higher than the front, a slight slope allowing the fire to shake down as the engine runs ; this keeps the fire on the move, the air spaces clean and retards the formation of clinker. When the bars slope, care should be taken in firing, and the back end, especially at the corners, should be well supplied with coal, or otherwise cold air will enter, with the bad effects already mentioned.

Some coal contains ingredients which form clinker when it is burnt; this is a melting together of various foreign matters, and to this the ash, etc., adheres, making a covering which sticks to the bars and prevents air from the ashpan having access to the fire, this will cause loss of steam, and in extreme cases melting of the bars themselves. When coal of this nature is used, a few flint stones, large enough to remain upon the bars and not fall through to the ashpan, should be sprinkled over the fire before commencing the day's work; this is a good precaution, as then if clinker does form it adheres to the stones instead of to the bars, and can be broken up and more easily lifted out of the firedoor by means of the "slice."

THE ASHPAN should be cleaned out as often as required, and a day's work should always be commenced with an empty ashpan, otherwise failure is courted. Air cannot get to the firebars freely enough to keep them cool if the ashpan is filled up, and consequently they melt or bend, the temperature of the contents of the firebox being considerably above the melting point of cast-iron ; the bars are only kept in a solid state by the proximity and inrush of cold air. When the dampers are shut the ashpan should be as nearly as possible air-tight; for, although this feature is not so important as in the smokebox, there are occasions when a tight ashpan is of assistance, as for instance, if the fire is dropped and it is necessary to move the engine whilst hot, especially if it has to pass over a cold pit, the closing of the damper-doors will prevent cold air from entering the hot firebox and causing leakages there, as already described.

When running, the firedoor and dampers should be so regulated that proper proportions of air should be admitted both above the fire as well as below the firebars, in order to obtain good combustion. The amount admitted at the firedoor will vary considerably with the grade of coal burned; the more bituminous samples requiring most.

The firebox sides and top, more often the latter, and the roof stay bolts will frequently become coated with a hard deposit, when small coal which has been well watered whilst in the bunker is burnt; this deposit also accumulates in the firebox ends of the tubes and over the whole of the tubeplate, the trouble being intensified when no brick arch is used. This substance can be cleaned off roughly with the "slice," and the tube ends pricked out with the tube pricker, the roof being roughly cleaned with the same tools, but when the engine is in the shed and comparatively cool, time spent *in* the firebox to thoroughly clean the plates will not be wasted and be amply repaid when the engine is running.

THE TUBES will have soot deposited in them as they tend to extinguish the flames of the fire owing to their restricted area, and also on account of their reduced temperature from the water surrounding them rapidly conducting the heat away. The soot should be cleaned out as often as necessary by means of tube rods, long pieces of wire from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in diameter, with a suitable handle formed at one end and a series of holes at the other, through these holes pieces of spunyarn or preferably unravelled Manilla rope of about six inches in length are threaded; the rod itself is long enough to conveniently go through the tubes, so that when it is passed through—all soot, etc , is cleaned out, either into the firebox at one end or the smokebox at the other. The reason for the preference for Manilla rope is that it is stiffer and will therefore brush better than spunyarn, which soon becomes "dead." The larger the tubes to be swept the more strands of rope will be needed, and consequently the more holes will be required in the rod end.

If the blower is kept on whilst the tubes are being swept, the soot will be carried upwards, and so clear of the operator; soot can be much more easily removed when the boiler is hot than when cold.

Steam or air jets are also used for cleaning tubes, the former has the objection, however, that when the tubes are long and the boiler cool a portion of the steam condenses and forms water which combines with the soot and stops the tubes at the ends farthest from that in which the jet is inserted. Scrapers are also used to a limited extent on tubes of large diameter.

As already mentioned, a SMOKEBOX that is not perfectly air-tight is likely to give trouble, if not attended to. Often the men who build up the smokebox are not careful enough to fit the plates together properly, thinking that a rough job like a smokebox can be finished anyhow, this is decidedly a mistake, for any leakages which admit air, not only impair the vacuum created by the blast, and so minimise its effect on the fire, but also allow the plates near the leaks to be burnt away, as air entering there causes combustion of the fine ashes drawn through the tubes.

If leaks are near the bottom of the smokebox, as at the joints of the tube-plate with the cylinders, and the side plates with the frames, especially at the corners which are likely to be faulty fits, the best remedy is to get a bucket full of heavy cement or fire-clay and thickly coat these parts with it, this will generally effectually prevent access of air, and will also preserve the plates. A layer of bricks and fire-clay over the top of the cylinders is also a precaution, as it prevents the ashes drawn through the tubes from coming in actual contact with the metal. Cylinders have often to be renewed by being too thin on top, not owing to wear in the bore by the piston, but to being corroded away by the combustion and chemical action of ingredients of the ashes.

LEAKY TUBES are often caused by bad firing or heavily forcing the engine. The former malpractice causes leakage by reason of the varying temperature of the firebox; when the fire is thin and bright, intense heat is given off but after a heavy charge of coal has been put in, a great reduction of temperature ensues. The tubes are affected by this before the tubeplate, as they are so much thinner and more closely in contact with the gases, consequently they contract and leave minute spaces between their circumference and the holes in the tubeplates through which water is forced. When a boiler is liable to this defect great care should be taken with it; the fire should be kept well alight and brightly burning, and very small charges of coal put on at each firing, the fire-door being kept as far as possible in the working position, and restored after each one or two shovelfuls of coal are introduced.

When entering a tunnel or terminal station, when the damper will have to be shut, partially, if not entirely, the above precautions should be carefully observed, and a medium bright fire, not too large, but sufficient to prevent the access of cold air to the tubes maintained. When tubes are leaking badly, bran put into the water-tank and allowed to work into the boiler with the water is often effective in mitigating the trouble but when this is done great care should be taken with the injectors, and they should both be operated and kept in good working order, as if one only is used the other may have its waterways clogged with the bran and then refuse to work when required.

Should a tube burst and allow the water to escape, it is necessary to stop it up entirely. This is usually done by means of cast-iron tube plugs, a supply of which are always carried on the engine; these are driven into each end of the defective tube. In such a contingency both injectors should be kept on, so that the water level may be maintained as far as possible, and the steam pressure reduced in the boiler, then the blower opened so that the steam and water may be drawn towards the smokebox and away from the firebox end of the tube, which should always be plugged first because it is the more awkward to get at, and also because it is desirable to preserve the fire; afterwards the smokebox end can be dealt with.

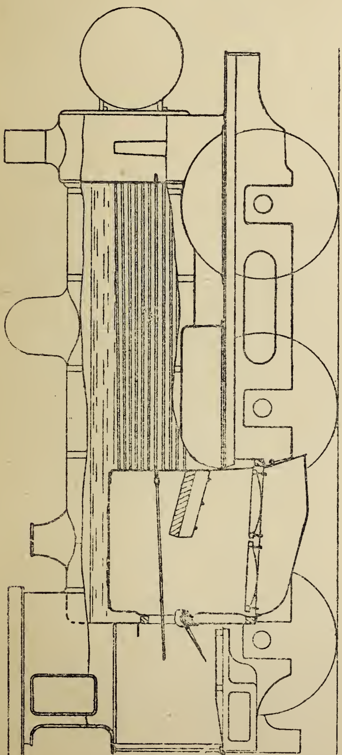


FIG. 2.

When the plugs have entered the tube ends, a few sharp blows should be administered to keep them in place, but care must be exercised to see that the tube end is not driven from its seating in the tubeplate at the same time, or a much more serious defect will be caused. It is not desirable to stand directly in front of a plug that is being driven in, as the steam and water pressure in the tube may drive it out again with considerable force. If, owing to the escaping steam, it is difficult to see the defective tube in the firebox, a piece of lighted oily waste placed on the brick arch may help, but if the "blow" is bad and this will not keep alight, it will be necessary to go to the smokebox end and put a tube-cleaning rod into the leaky tube, which can be usually seen from that end, push it through to the firebox, and then insert the plug into that hole the rod appears in. Fig. 2 shows a section through a locomotive boiler, and indicates the method in which these plugs are put in—that at the firebox end by means of the "plugging iron," and that of the smokebox by hand.

If the leak is so bad that it is not possible to temporarily remedy it, and the engine is some distance away from a station whence assistance can be obtained, it will be necessary to work home and the fire must be taken out or smothered by throwing in ballast or earth, and when the temperature and pressure have fallen, the fireman must get into the firebox, put in the plug by hand and fix it; the fire can then be re-lighted and the engine proceed on its journey. If no proper plugs are upon the engine a piece of wood cut to fit tightly in the tube will do if it is driven well into the tube, for all that projects from the end will naturally be burnt off. The bursting of tubes is not nearly so common an occurrence now as it was in the early days of railroading, owing to the universal use of weldless and solid drawn tubes for locomotive boilers.

Various other parts of the boiler, particularly stays and joints in the structure itself, may give trouble by leaking, and if these defects are in the barrel or any other portion it is quite out of the engineman's power to remedy them, and the troubles should be at once reported for attention. Defects of this nature in the internal firebox, however, may be partially counteracted by the same careful firing that is beneficial when leaky tubes are encountered.

Engines should be moved as little as possible with their own steam whilst hot, and after the fire has been dropped, for a large body of cold air will be drawn through the tubes by the blast, causing leakage there by contraction. For the same reason the injectors should never be put on after removal of the fire.

LEAKAGE AT THE STAYS is often caused by accumulation of dirt or scale inside the boiler, which prevents the water from having access to the plates and stays, and causes local overheating and consequent leakage; frequent washing out should lessen the possibilities of this, but if it continues the stays require caulking at their inside ends.

PRIMING, or the mixture of a large proportion of water with the steam as it leaves the boiler, is a very trying and sometimes dangerous trouble. It may be due to the water level being too high, bringing the surface of the water too near the place at which the steam is drawn off. The remedy in this case is obvious: carry a lower water level. Priming is, however, more often a result of the unsuitability of the water carried, greasy or dirty water will cause it, and it will occur if the water is not changed frequently. It can sometimes be partially cured by adding a small quantity of petroleum to the water in the tender, but this must be done cautiously, or it will cause the tubes to leak.

The best way to reduce the priming when running is to close the regulator as nearly as possible, thus leaving only a small outlet for the steam (wire-drawing it, as it is termed). This has the effect of throwing back the moisture, and when the surface of the water in the boiler has settled down, the regulator is gradually and steadily opened to the required amount. The regulator handle should not be moved too suddenly at any time, but special care must be exercised when the boiler has a tendency to prime.

SCUM COCKS are sometimes fitted at about the water level, then the surface of the water which contains some of the lighter bodies liable to cause priming can be blown off at suitable intervals. The same result can be secured when no scum cocks are fitted by filling the boiler as full as possible, and blowing off hard at the safety valves, lifting them slightly for this purpose. Any surplus water can afterwards be let out at the blow off cock until the proper level is reached. When an engine is running with water that is liable to prime, the level of the top of the water, as shown by the water gauge, cannot be entirely depended upon, as it will fall very considerably when the regulator is closed; care should therefore be taken not to run with it so low that the firebox crownplate will be uncovered when steam is shut off. Priming is dangerous, as the water works into the cylinders, and being non-compressible is liable to break the covers, pistons, etc., unless released from the cocks and even if nothing breaks, it strains the working parts of the motion.

THE INJECTOR FEED will, with a heavy train, have to be kept on almost continually in order to maintain the necessary water level in the boiler. It should be noted here that it is always easier to keep up a constant water level and steam pressure than to raise them again if once allowed to fall.

The refusal of the injectors to work is a common complaint on locomotives in service. It is often due to priming, for steam highly charged with water will not operate injectors. When, however, the failure is not traceable to this cause the injector should be examined, and the small cock usually fitted at the delivery end of it opened to let the water out of the delivery pipe; this may enable the injector to start. The cock is shown at A, Fig. 3. If steam blows out of this cock when open it is a sign that the valve in the clack box fitted on the boiler, shown at B, is sticking up, and this must be closed before the injector will start. A few taps with a hammer, or preferably a block of wood, will often cause it to fall into its place. In the event of both injectors absolutely refusing to act and no remedies avail, so that water cannot be fed into the boiler, it is advisable to proceed very cautiously with the engine so that the water level may not fall too

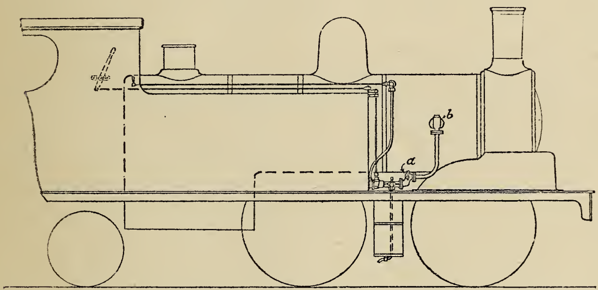


Fig. 3.

low, procure assistance, and come off the train into a siding clear of the main line. The fire should then be thrown out to allow the engine to cool down, and when the pressure has fallen, take off the cap of each clackbox and examine the valve, remove the obstruction if there be one, replace the valve, and if sufficient water is left in the boiler to safely do it, raise steam again and work home.

An injector that repeatedly refuses to work or flies off frequently should be booked to be examined, as it is probable some of the cones inside require attention if loose or badly worn, or if they are not in their proper positions a good working injector cannot be secured. Many injectors are now made with a clackbox in combination, and are fitted with a stop-cock, by closing which any part of the injector can be examined whilst the boiler is under steam. This type of injector is usually fitted to the firebox front, and has an internal delivery pipe leading to the boiler barrel, which must be kept free from deposit.

After repeated trials at starting an injector it will become heated to the temperature of the steam, and it will be necessary to allow it to cool down by allowing the feed to run through it before it can be "coaxed" into feeding the boiler; with the last-named type fitted to the firebox front, a handfull of waste and a bucket of cold water will sometimes overcome the difficulty.

REGULATORS will often work very stiffly, which can be traced to the packing in the stuffing box upon the front being too tight, and to a want of lubrication there. It is a good plan to have a hole in the top of the gland, through which oil can be fed to the packing. The valve faces also get dry and cause the valves to work badly. This can be prevented by putting a little oil in the water tank and allowing the injectors to feed it into the boiler, but this must be carefully done as already noted. A lubricator is sometimes fitted on the dome for oiling the valve faces.

Failure of regulators of the slide-valve type, due to breakage, is most likely to occur at the pin joint upon the arm of the rod lifting the valves, or to the joint connecting the valves to the lifting rod. If the former fails and the valves cannot be lifted, they will both close the ports, and consequently the engine cannot be moved, causing a total stoppage. If, however, the top joint fails, and the small valve only will open the ports (in most cases the larger valve alone has a lip at the top preventing it from falling off the face when uncoupled) the train can still be moved, if not too heavy, and when it is necessary to stop, as the regulator cannot be closed, the engine can be put into mid-gear, or even reversed if necessary. The brakes can also be applied, and the cylinder cocks opened to prevent steam accumulating in the cylinders. If when running there should be any risk of the engine becoming unmanageable, the best procedure is to let the steam pressure down, and so reduce the power.

Water Gauge Glasses should be well looked after, as the bursting of one may prove an awkward accident even if the column is provided with a protector the automatic valves fail to act. This contingency should, therefore, be anticipated when possible, generally the glass wears thin at the edges of the gland nuts, and it should be taken out and replaced by a new one before it becomes dangerous. It is advisable for drivers to carry one or two spare glasses with them cut to correct length, so that when breakage occurs a new one may be put in without loss of time.

In putting in a New Glass the top nut of the fitting should be taken out and the old glass removed, an operation much easier to perform if the glass is not broken; if ordinary hemp packing is used, it should be taken out and the passage for the new glass cleared, the latter must then be put in from the top, a short piece of wood of about the same diameter as the glass being introduced above and the top nut screwed down on to it. This will hold the glass down and prevent any of the packing working under it and partially blocking up the waterway of the column, which might cause a false water level to be shown in the glass. When the top and bottom glands are repacked the piece of wood should be removed and top nut replaced. If cones are used for packing, as they often are, the operation is much simplified, as the gland nuts will simply have to be slacked back, the old glass taken out and the new one put in, the glass being held down as before until the glands are screwed up.

In making the screw joint at the top, or, in fact, any screwed joint, red lead should not be used, as it sets hard and increases the risk of breaking the fittings should these have to be hurriedly disconnected; a little tallow or, failing that, oil should alone be used.

It is good policy for the driver himself to examine the water gauges and see that they are in good working order, by occasionally disconnecting them and cleaning the inside valves and the steam and waterways. He is one of the most likely persons to be scalded if they should fail when running, and therefore one of the most interested; if the cleaning is systematically done it will not be found a troublesome task. Attention is especially necessary when the columns are of the automatic shut-off kind, as scale from the water may clog up the moving parts, and then should the glass burst they will not act.

The Test Cocks, which are always fitted in addition to the gauge column, should also receive attention, the plug being taken out and oiled frequently, otherwise it is likely to set fast in the body and the handle be broken off before it can be moved. Slacking back about once a week will prevent this, and then when required they will be found in good working order, and the knowledge that they are so will prevent a great deal of anxiety.

A Blowing Joint on the front tubeplate where the elbow for the steam pipe to the cylinders is fixed is a very bad defect, as it destroys the effect of the blast upon the fire, and when this happens it is desirable to keep the blower on to tend to draw the steam away from the tube ends and help maintain a good draft.

The best precaution against failure from any of the causes above-mentioned are to carefully examine the boiler and fittings before each trip, and to exercise constant watchfulness during the running, and as far as possible remedy small defects before they reach dangerous proportions.

THE VARIOUS STRAINS put upon the structure of the boiler by varying steam pressures and consequent temperatures are considerable, and in order to guard against them, the pressure should be kept as nearly as possible uniform, and the water level the same ; if the latter is allowed to fall and the steam pressure to rise, to be subsequently reduced by the injection of a large quantity of cold water, the sudden lowering of temperature which ensues will cause the joints of the boiler to be unduly strained.

Opening the firehole door, when there is but a thin fire on the bars, and whilst the blower is on, or the regulator open will cause a considerable draft of air through the tubes, and contract them in their holes in the tube-plate and cause leakage.

THE CLEANING of the inner surfaces of the boiler is of great importance if it is desired to add to its efficiency and life. The efficiency is increased by the removal of scale, as then the heat is more effectually transferred through the plates from the fire to the water, whilst the life of the boiler is preserved by the absence of scale and deposit on the inside, they being non-conductors of heat, whose presence prevent the conveyance of the heat to the water which should protect the plates and keep them comparatively cool.

PERIODICAL CLEANING out of the boiler is most necessary and should be carefully and thoroughly done, the interval between these washings out varies very considerably in different localities ; the quality of the water used largely determines the periods, some water being so good as to make little or no deposit, whilst some is so bad that if the boiler is left for but a short time without removal of the dirt, the heating surfaces would be almost useless, whilst liability to damage by overheating would increase.

The usual method of detaching scale and removing it from the inner surfaces of a locomotive boiler, always more or less inaccessible, is by means of jets of water directed through the plug-holes provided in various places for the purpose, a cleaning rod of steel wire is inserted in an adjacent hole to that into which the water jet is directed, and by

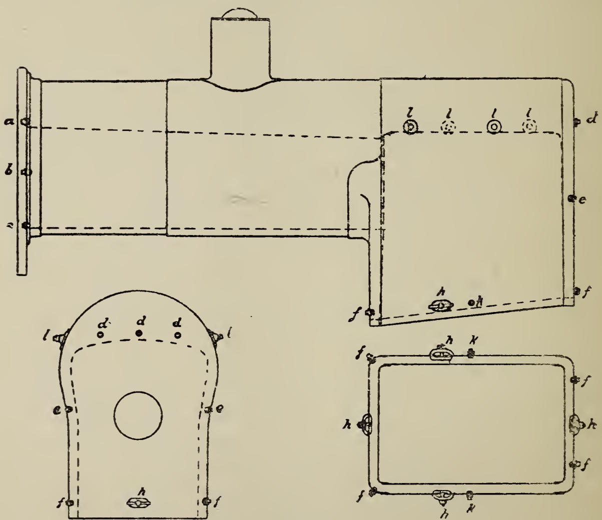


Fig. 4.

being continually worked about it loosens the scale, and the water carries it away to the lowest point of the boiler, round the firebox foundation ring, whence it is finally removed through the plugs or handholes provided there.

The usual positions for MUD PLUGS are shown in Fig. 4. In the front, or smokebox tube-plate, there are generally two just above the top row of tubes, one on each side of the centre clear of the blast-pipe at A, sometimes two others among the tubes as at B, and two more along the last row of tubes near the bottom of the boiler barrel as at C. In the back-plate of the boiler three or four are placed along the level of the top of the copper box as at D, others at the sides of the copper box as at E, and several round the bottom of the firebox, just above the foundation ring, the positions at F.F. being the most common; all these are varied a little on different engines to make them more easy of access.

In localities where large quantities of dirt and scale are formed, mud-holes or hand-holes larger than the plugs are provided through which it is possible to get out the larger pieces of scale. The usual positions for these are at H.H., and in cases where hand-holes are used the mud-plugs at K are not put in.

Some engines, especially those fitted with Belpaire boxes, have two or three plugs situated on each side of the outer firebox, at the level of the top of the inner box as at L, for the direction of a cross jet of water as well as those injected longitudinally.

The size of the mud plugs vary, but are commonly from about 1¼-in. at the smaller end, enlarging to 1½-in. diameter at the larger, threaded with a tapering thread, so that as the holes and plugs wear the holes may be enlarged a little by means of a taper tap, and another portion of the plug used. A square head provides for the use of a spanner to screw them home.

As the thickness of the boiler plate does not allow for many threads to be formed at the plug holes, a patch is often studded on to the boiler. This has a boss with a hole tapped through, and when it is worn the patch is removed and another put on.

Washing Out.—When a boiler requires washing out, it should be allowed to cool down before running the water off, otherwise the plates will be strained by the sudden contraction; when it is sufficiently cooled the water should be allowed to escape by the blow-off cock, placed at the level of the top of the foundation ring either upon one side or at the front or back of the firebox, as found most convenient on the particular engine.

If, for any reason, it is found necessary to quickly cool an engine, a good way is to let all the steam blow out through the various steam cocks, then take out one of the top mud plugs and insert the nozzle of the wash-out pipe; open the blow-off cock slightly, and as the hot water escapes at the bottom, allow cold water to enter at the top, the hot will then be quickly, yet gradually, replaced by cold, and the boiler is cooled without unduly straining it.

When the plugs are removed the nozzle of the hose pipe is inserted in each hole in turn and water injected through it, the cleaning rod being worked through an adjacent hole at the same time. Commencing at the plugholes along the top of the firebox, the highest point, the dirt is dislodged from it first, then the sides of the firebox are dealt with, and finally the front tube plate, washing the dirt down among the tubes until it accumulates at the bottom of the barrel; from there it is driven towards the firebox, down the sides of which it falls ready for removal. A final wash all round in the same order is desirable, and then the foundation ring is cleared and all dirt that has accumulated there removed through the mud or hand holes.

After washing out all the plugs must be replaced and screwed home tight, except one of the top ones; here the nozzle of the hose pipe is inserted and the boiler filled up with water ready for lighting the fire.

Care should be taken in screwing up all the plugs before lighting up, as it is very dangerous to attempt to tighten them when steam has been raised.

Any plug that does not fit tightly in the hole but allows steam to blow past should be taken out and the hole retapped to renew the thread, otherwise the blowing steam will make future tightness still more difficult, as it wears away the thread.

Four NOZZLES are usually required to properly wash out a boiler—three straight ones, one short A, Fig. 5, one medium, B, one long, C, and one bent, D. The medium one is used for the top and sides of the box, and in all holes requiring a straight jet; the short one for holes in which the longer one cannot be put, and for filling up the boiler; whilst the bent one is used for directing a jet along the back plate. The long straight jet is only used when the tubes are "sifted." The operation of

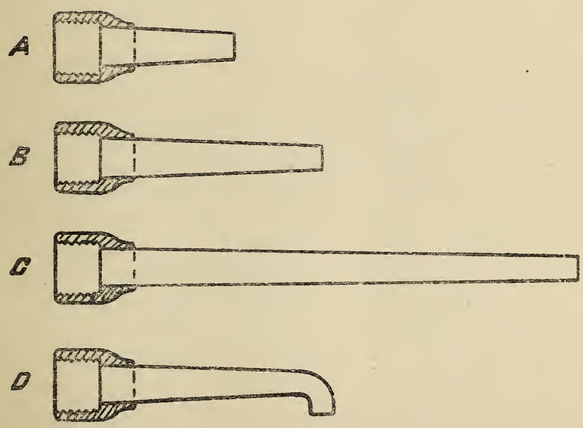


FIG. 5.

"sifting" consists in the removal of several of the tubes in order that dirt and scale which has evaded the usual cleaning operations, and has got thickly embedded among them, may be cleared out.

The nozzles illustrated are attached in turn to a flexible hose pipe which is coupled at one end to a water hydrant, and has at the other a screw thread to accommodate them.

In the washing out operations above described the water used is assumed to be delivered at the pressure of the main, merely a few pounds, but in many sheds, plant is provided by means of which the water is forced at a pressure of some 60 lbs. per sq. in., and then the removal of scale is much more effectually performed.

The more modern method of washing out is to use hot water at 100 lbs. pressure, a permanent steam pipe being provided in the shed for supplying boiler steam to injectors fitted to carry the water through flexible hose pipes to the nozzles, and delivering it at high pressure and temperature.

The advantage of using hot water is that the scale is more readily removed by it than it is by cold, and no detrimental effect is produced on the boiler if this is hot when being washed out.

To ascertain that all the scale is removed, a good plan is to take a piece of greasy waste, light it and fix it to the end of a rod long enough to reach to all the places visible through the plug holes, this can be inserted at the different holes, and if moved about all the interior can be seen, and scale not removed detected; this precaution is especially necessary along the firebox sides as dirt is liable to accumulate on the stays, and if not removed local overheating is likely to occur, and leaky stays result.

ENGINE FAILURES AND REMEDIES.

WHEN taking charge of an engine, and before leaving the shed, it is necessary that the driver should personally see that everything is in good working order about it, and that it is supplied with fuel and water, and has a full equipment of tools. The different oil cups should be correctly adjusted and filled with lubricant, and all the visible parts of the motion carefully examined.

At the end of the day's work, too, all repairs, etc., that may be required, or any defects noticed during the run, should be entered in the shed-book appointed for the purpose, so that they may receive proper attention before the engine goes out again.

With the most careful examination, however, there will always be liability to failure in service, owing to hidden flaws, weaknesses or breakdowns; for instance, priming may, as has already been mentioned, cause damage to various parts of the cylinders and strain the motion generally, whilst slipping, especially if sand be applied to the rails when the wheels are rapidly revolving and the regulator open, may cause the motion, coupling rods, etc., to be very severely strained, even to beyond the point they are capable of resisting, and then breakage or failure is almost certain to ensue.

Before considering these mishaps and failures, or actually dealing with any specific defect, a few words should be given upon the relative positions of the various parts of the motion with regard to each other. This will be convenient for reference, and enable many points to be more easily explained.

Taking an inside cylindered engine, it being the more common type in this country, with the cylinders placed between the frame-plates, the connecting rods are connected to the cranks, of which two are formed upon the driving axle.

These CRANKS are set so that one of them is a quarter of a turn in advance of the other; then when one piston is at the end of its stroke and cylinder, with its crank upon the dead centre, and exerting no turning effect, the other one is at about the centre of its stroke, and its crank is in the position for exerting the maximum power, thus each crank in turn performs its share in the rotation of the driving-wheels. It is by the position of the two cranks in regard to each other that it is possible to tell whether an engine is right or left-handed.

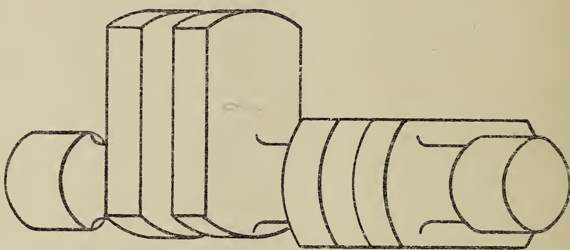


FIG. 1.

When a crank axle is revolved away from the observer, if that crank upon his right is a quarter of a turn in advance of that upon his left, the crank is said to be a "right-handed" one; if, however, that upon his left is in advance of that on his right by a quarter turn, it is termed "left-handed." Fig. 1 illustrates a right-handed crank, and Fig. 2 a left-handed one.

It does not affect the working of an engine whether the cranks are right or left-handed, but it does modify the relative positions of the parts of the motion when a driver sets his engine to "try her over." For convenience of reference names and numbers are given to the various positions of the cranks during their revolutions. These names may vary somewhat on different railways, but those given herein are fairly common.

When an engine stands with one piston in its extreme front position, or end of its stroke, the crank that is coupled to it is said to be on its "front centre"; when the piston has moved to the opposite end of the cylinder, the crank is on its "back centre"; when the crank is exactly midway between the front and back centres and uppermost it is said to be on its "top centre," and when below on its "bottom centre." These four positions divide the revolution into four equal parts, and are termed "centres." When the crank is halfway between front and bottom centres it is on its "bottom front

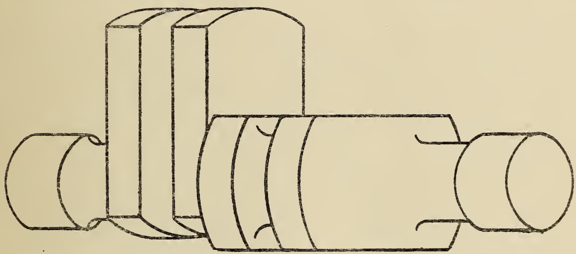


FIG. 2.

quarter," midway between bottom and back on its "bottom back quarter," between back and top upon its "top back quarter," and when midway between top and front centres on its "top front quarter." The distance between each adjacent centres is thus sub-divided into two portions, and the path circle into eight equal parts. These terms are, of course, purely conventional, and are merely used for convenience of reference.

The POSITIONS are numbered as follows:—For right-handed engines: When the R crank is upon the front centre and the L crank upon the top, the revolution is assumed to commence, and this is termed the "first" position; turning an eighth of a revolution the R crank reaches the "bottom front quarter," the L being upon the "top front quarter," the "second" position, and so on. Each eighth of a turn gives a "position." Fig. 3 shows a right-handed crank in each of the positions.

In a left-handed engine the same positions of the R hand-crank are taken, but the L hand-crank will be half a revolution in advance of the L hand-crank of the right-handed engines. Thus, in the "first" position the R crank is on the front and the left upon the bottom; "second" position R crank is on "bottom front quarter," L crank is on "bottom back quarter," and so on.

The COUPLING OR SIDE RODS are placed exactly opposite the cranks upon the same side of the engine. In Fig. 3 the small circles denote the positions of the coupling-rod pins, those in full lines being the left-hand side, exactly opposite the L inside crank, and those dotted on the right-hand pins being opposite the R inside crank.

The LOCATION OF THE SLIDE VALVES can be easily found on consideration, and as the connecting and piston rods upon each side of the engine are always of the same length, it follows that the position of the crosshead will indicate the position of the piston connected to it. Thus, if the R crosshead is at the centre of the stroke, the R piston will also be at the centre of its stroke, etc. As the steam is admitted to the steam chest it is by the aid of the slide valves allowed to enter the port at one end of the cylinder, and force the piston to the opposite end, the slide valve at the same time providing, by means of its cavity for the escape of any steam to the blast pipe which may be on the other side of the piston. As it moves along the valve opens the other port to steam, and connects the first-mentioned one to exhaust; thus the piston is alternately driven to and fro in the cylinder, imparting motion to the driving wheels.

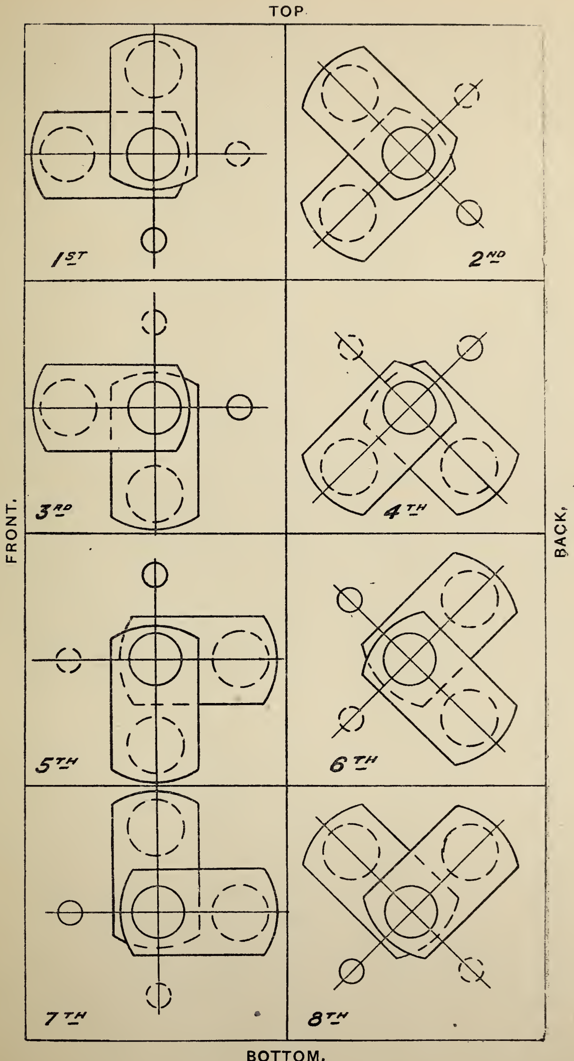


FIG. 3.

By the foregoing the ports open to steam can be easily ascertained. Thus, if the R crank is on the top centre, the R piston will be in about the centre of its stroke, and the L crank will be on the back centre, a dead position as far as any rotation of the crank axle by it is concerned, and the R crank will therefore have to do all the moving of the axle. If, now, the reversing gear is put into the "fore" position, this crank must be pulled over towards the cylinder to revolve the wheels in the proper direction, and as the steam has to be admitted behind the piston, the back port must be open to steam. If it is desired to move backwards, the lever is shifted into "back" gear and steam admitted through the front port to move the piston towards the back of the cylinder. If the lever is put into "mid" gear the slide valve occupies a position midway between these two extremes and closes the ports. During these movements the L valve has not been shifted nearly so much as the R one has; in fact, only the difference by which the lead varies when in "full" and "mid" gears. In engines fitted with Joy's gear and other motions where the lead is constant the valve would not be moved at all.

When the wheels have turned half a revolution and the L crank is on the top centre, the L valve will have greatest travel, and the R valve will simply vary as the lead varies. These positions of the valves will be further referred to in the description of "blows" from failures.

The Defects to Cylinders most likely to occur in working, either from priming, wear or other causes, are breakages of the port bars or bridges between the steam and exhaust ports and passages; these are liable to crack or break, either by reason of faulty lubrication or broken valves, which may catch them in working. The cylinders themselves may break or crack in places when worn thin, generally along the top, where the smokebox ashes, etc., accumulate and destroy the metal. Covers, pistons and rods, valves, spindles and stuffing boxes will also get broken or blow, and these parts being fairly accessible, they are comparatively easy to see; but the failures inside the cylinders and steam chest which are not visible without disconnecting the covers, etc., have to be detected by noticing the beats the steam makes when escaping up the blast pipe.

When steam is admitted to the steam chests of simple engines, and the engine is in working order, for each revolution of the driving wheels four beats will be given; these should follow each other regularly, with a correct interval between. Where instead of four equal beats, say three beats and a roar, or "blow," is given, it may be at once assumed that some internal part of the mechanism has become defective, and by observing the position of the cranks when the blow is given, the particular defect may be located.

If when an engine is running, and during the whole time the regulator is open, a "blow" is given up the chimney in addition to the four distinct beats, it is an indication that the faces of one or both of the valves are bad, so that steam passes the port bar and so up the exhaust pipe. To ascertain which valve is at fault the engine should be set in the "first" position (R crank on front L crank on top) and lever put in mid-gear. This will test the L valve, as its ports should be closed in this position; on opening the cylinder cocks if any steam blows out of those on the left side it proves the L valve to be defective. To test the R valve put engine in "third" position, R crank on top, and a blow out of R cylinder cocks proves the R valve defective.

Such defects, unless very serious, should not be sufficient to make it necessary to give up a train, but they should be booked at the shed, so that the valve or valves may be examined and renewed if desirable. The engines of some railways have a few holes drilled in the back of the flange of the valves to the depth that the flanges are allowed to wear, so that when too thin they blow before breakage, and intimate it is time to have them renewed.

Should a serious defect present itself which necessitates the uncoupling or disconnecting of one side of the engine, it should be located by the engineman, if possible, before stopping, from observation of the beats and blows, and he should then be able to stop his engine in such a position that he can conveniently uncouple the necessary attachments and disconnect the broken or defective member, without wasting valuable time in examining and testing valves and pistons; a broken piston, for instance, would give two beats and two blows for each revolution of the crank, and there should be no difficulty in ascertaining upon which side of the engine the damage exists.

If, whilst the engine is moving slowly, notched up in its running position with steam on, a b ow is given as the R crank passes the front centre, and continues until it reaches about the bottom centre, followed by an ordinary beat, then as the R crank reaches the back centre another blow, continuing until the crank passes the top, followed by an ordinary beat, it proves that the R piston is defective, allowing the steam to pass, because the R valve opens the R front port to steam as the crank is at the front, and there should only be a beat from the left hand side, if a heavy blow is commenced it is caused by the lead steam passing by the piston, and escaping directly up the chimney through the back port and the cavity of the valve. When the point of cut-off is reached the front valve is closed to steam and the blow stops; then, as the back port is opened the steam blows by the piston, through the front port to the blast pipe, as before. If the blow is given when the L crank is in the positions indicated it of course follows that it is the L piston that is at fault.

The magnitude of blows will, as a rule, be sufficient to indicate whether they are caused by a badly broken piston head, or from leaky or defective piston rings only. If they are very serious, and a broken piston is feared, it will be best to uncouple the broken side, as pieces of the broken head may become detached and catch in the ports, or get between the portion of the piston remaining attached to the piston rod, and one or the other of the end covers, and break them. Leaky rings, however, need not necessarily cause a failure, and if possible the run should be continued unless a convenient depot is reached for changing engines ; the trouble however, should be booked and the rings put into proper working order before the engine again comes out.

If it is necessary to uncouple, the slide valve should be closed first, when possible, as otherwise if the regulator leaks at all steam may accumulate in the cylinder and move the piston when the connecting rod is uncoupled from the crosshead, and cause injury to the men working on it, or do damage to the engine, but the methods of doing this work will be left until the blows have been dealt with.

Supposing a blow is detected and cannot be traced when running, the engine should be put into a siding where no delay is caused to traffic, etc., and the valves and pistons tested by steam. There are two methods of setting the engine for doing this work, both having their advocates, the first is with the cranks on the centres, and the second with the cranks on the quarters. The former method tests one side of the engine at a time, and the latter one end, that is front or back end of cylinders, etc.

The best positions for testing on the centres are the first position for trying the L hand side, and the third position for trying the R hand side, because in these the side that is not being examined has its crank upon the front centre, for as it is usual to set all the rods in the motion a little short, to allow for expansion when heated, and also for the engine settling upon the springs, there is more likelihood of an ample lead being provided at the front end than at the back, so that the port at the front end is not closed in any position of the lever.

For testing on the quarters the best positions are the second for testing the front end, and the sixth for testing the back end, as then the small ends are in a straight line across the engine, and lay exactly side by side, so that by observing them it is easier to set the cranks as near as possible in the right positions.

A defective piston can best be determined by a blow up the blast pipe rather than by escape from the cylinder cocks, as the tendency for the steam passing by the piston is to go up the blast pipe by way of the port at the opposite end of the cylinder in preference to passing through the small hole in the cylinder cock; when examining blows from leaky or defective valves, port bars or faces, however, there is often a saving in time by using the cocks in order to locate the defect.

Method of Setting on Centres.—Set the engine in first position, R crank on front centre, L crank on top centre, and put the brakes hard on so that the engine cannot move, put lever into fore gear and open the regulator a little and a blow is given up the chimney, on pulling up the lever into mid gear this stops, but if this commences again as back gear is reached it indicates that the L piston is defective and allows steam to pass it, as before described; if however the blow is not given in both fore and back gear, open the cylinder cocks and observe them as well as the chimney and see which the steam blows out of as the lever is moved. If the blow up the chimney is given in fore, but not in back gear, and steam blows out of L back cock in fore gear, but not in back gear, the left back port bar is defective, and allows steam to pass direct from the steam chest to the exhaust port as long as the slide valve leaves the back port open to steam, and the blows from the left back cock stopping as the valve closes, proves that the valve is not at fault. If, however, the blow is given from the left back cock in both fore and mid gear, but not in back gear, the back lap of left valve is defective, and does not close the port to steam. If no blow is given up the chimney in fore and mid gear, but there is one in back gear, and no blow from the cylinder cocks on left-hand side in mid gear, the left front port bar is at fault. If there is a blow in mid gear from left front cock it proves that the front lap of left valve is bad and allows steam to pass by it when the port should be closed. If a blow up the chimney is given in all positions of the gear it proceeds from some defect in the other side of the engine, and gets through the opening for lead upon that side, and herein lies the advantage of setting the engine with the crank of the side not being tested upon the front centre, for, then if there is a difference in the lead at either end of the cylinder, it is more likely to be noticeable there, the port being always open, otherwise, if the lead was less, and became still less as mid gear was reached, and if the engine had been set in the fifth position with R crank upon the back centre, it would be possible to have a blow in fore gear and none in back gear, then it would be feasible to attribute it to a defective front port bar, whereas the actual fault might be a leaky R piston, for the engine might have lead in fore gear but not in back gear. Such an error would not be so likely to occur if the piston was placed at the front end, as then if the lead was greater an error in the setting of the valves would not be so noticeable, and would not materially interfere with the blows.

If a blow is given all round, or if a defect is known to exist by reason of blows, given when running, yet none is noticed in the above position, the cause of it has not been located, and the engine should be set in the third position R crank on bottom centre, L crank on front centre, the lever put into fore gear, and a little steam applied; then, if the blow is given up the chimney and stops as mid gear is reached, commencing again as back gear is approached, the R piston is defective. If the blow is given up the chimney in fore, but not in mid or back gear, and there is no blow from R front cock in mid gear, the R front port bar is at fault. If, however, the blow is from the R front cock in mid gear, the front lap of R valve is defective.

If, when the engine is set in the first position and no blow is given from the chimney in any position of the lever, but on setting it in the third position a blow is given up the chimney in back gear only, and there is no blow from R back cock in mid gear, it follows that the valve is doing its duty, and the defect lies in the R back port bar; if the blow is given from the R back cock in mid gear, it proves that the back lap of R valve is defective, and not covering the ports when in its middle position.

If, instead of testing the engine by setting it on the centres as above described, the other method, that of setting it on the quarters, is chosen, the mode of procedure will be as follows:—

Set the engine in second position, R crank on bottom front quarter, L crank on top front quarter; then in the sixth position, R crank on top back quarter, L crank on bottom back quarter, and watch the chimney and the cock blows as before.

When the engine is in fore gear, and a blow is given up the chimney in both second and sixth positions, the R piston is at fault. If the blow is given in both positions with the lever in back gear, the L piston is defective.

If the chimney blow is given in fore gear in the second but not in the sixth positions, it may proceed either from the R front port bar or front lap of R valve, and to determine exactly which of the two it is, set the engine in the sixth position and put the lever into back gear, and observe which cocks are emitting steam; if from the R front cock, it is the front lap of R valve, but if no steam issues from the cock it is the R front port bar that is defective.

When a blow up the chimney is given in forward gear in the sixth but not in the second position, it is the back lap of R valve, or R back port bar, and these again have to be separated by testing in the second position with lever in back gear, then a blow from the R back cock proves it to be the back lap of R valve, but no blow from this cock determines that the R back port bar is at fault.

If a blow up the chimney is given when the lever is in back gear in the second but not in the sixth position, either the L front port bar or the front lap of L valve is defective, and to ascertain which of them it is, put the lever into fore gear and the engine in the sixth position, and a blow from the L front cock indicates front lap of L valve defective, whilst no blow from this cock shows that it is the L front port bar that is causing the trouble.

If a blow up the chimney is given in the sixth but not in the second position with lever in back gear, it is either the L back port bar or back lap of L valve, therefore put the engine in the second position and lever into fore gear, and a blow from the L back cock indicates the back lap of the L valve, and no blow from this cock proves that the L back port bar is defective.

Having located the defect by the blows, or seen it if visible, and determined that it is necessary to uncouple the defective side of the engine and work on with the other, it will be best in all cases, as already observed, to disconnect the valve gear and fix the slide valve in its central position, and thus close the ports to steam to remove any risk of danger from the piston and connecting rod moving.

As VALVE GEARS vary very much in their details, a few explanatory words are necessary on their differences. Taking first the Stephenson, or shifting link motion, it being the most common form of valve gearing on locomotives; two eccentrics for each cylinder are fixed side by side upon the driving axle, one for moving forwards and the other for moving backwards, each of these are connected by means of eccentric rods, from the straps upon the eccentric sheaves to the quadrant link, the fore-gear rod being attached to the top of the link and the back-gear rod to the bottom of it. The quadrant block, which is carried by the intermediate valve-spindle, slides in the slot of the link, so that as the link is lowered down, it is moved nearer to the top of the link, and the fore-gear eccentric operates the valve for the engine to move forward, then if the link is lifted up, the bottom or back-gear eccentric and rod works the valve for moving the engine backwards. When the link occupies a mid-position, the effect of the eccentrics neutralise each other, and there is practically no movement of the valves.

In these respects all engines fitted with this form of link-motion are alike, but they vary in the way the link is moved and hung, and it is necessary to mention these differences in order. There are four different ways of arranging the parts, first the link may have saddle-pins upon it at the centre with the weigh-shaft above, and the swing-links then reach down to these; secondly, the saddle-pins may be at the centre of the link, as in the first case, but the weigh-shaft is below, and the swing-

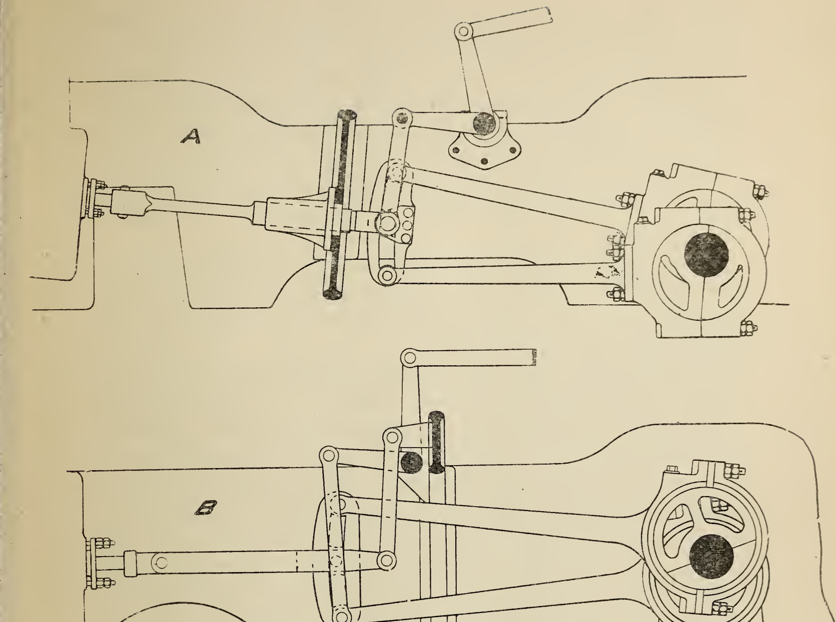


FIG. 4.

links then extend up to them; thirdly with no saddles, the weigh-shaft above, and the swing-links reaching down to the bottom of the link and coupling on to the same pin as the back-gear eccentric rods; and, fourthly, the weigh-shaft, etc., below, with the swing-links coupled to the tore-gearing eccentric rod pin at the top of the link. The first two methods are most common, the other two, however, are often met with.

The shape of the intermediate valve-spindle, and the length of its slot, in which the quadrant-link works, will also affect the work to be done in uncoupling the valve-gear.

Assuming that the motion is arranged as in A, Fig. 4, the first-mentioned method, it will be found necessary to take down both the eccentric rods and put the defective side out of action altogether, as the slot in the intermediate valve-spindle is not deep enough to allow the link to travel in it if the quadrant-block is removed and the rods left up, with the valve in its central position, the best way, therefore, to commence the uncoupling is to first put the valve in its central position, if the defective side has the crank upon the top or bottom centre, this can be done by putting the engine into mid-gear, or if the other side is upon top or bottom centre, measure the distance of its intermediate valve-spindle socket from the gland and then place the side to be uncoupled in the same position, when the eccentric rods are off, and lock the spindle and valve by "cocking" the gland, an operation performed by slackening the nuts upon one of the gland studs and tightening up those upon the other, until the gland grips the rod and prevents it from moving.

If it is possible to move the engine, the most convenient position for getting down the motion when hung in the manner under notice is to place the cranks in the 8th position, as then they are as far out of the way as possible; also, the eccentric strap-bolts are all fairly accessible; it will be found in most cases, best to take down the straps with the rods, rather than to take the rods down alone by uncoupling at the butt ends when the bolts are in very awkward places, and also by removing the straps all anxiety as to whether they will foul the frame-stay or fire-box front when running will be obviated.

It may be easier to take out the pins through the forked end of the rods and the quadrant-link first, as then the rod may be moved up and down to get the strap-bolts into better positions; if so, put the engine into fore-gear to get down the back-gear rod, and into back-gear to get down the fore-gear rod, as they will then each be further from the saddles and easier to get at. Knock out the taper-pins which hold the link-pins, by first closing the split at the bottom carefully, then give them a smart blow fairly on their points, and they should fly out; a little time spent in doing this properly is not wasted, for if too hurriedly done the pins may be "burred" over at the points and a considerable amount of work caused in getting them out, unless a handy pin-punch is carried by the driver.

If, on careful observation, it is possible to move with the link still up, as would be the case if the defect made it advisable to run with the back port open to steam, then as it is only necessary to take out the quadrant block, the 8th position of the crank, with engine in back gear will be the best one, the pins through the quadrant block being then out of the way of the saddles on the link. As it is in no position possible to get a blow on the inner ends of these pins to drive them out, owing to the proximity of the other valve spindle, it will be necessary to ease them out carefully by means of a flat chisel or small "tommy bar" pressed against the inside end of them and the other valve spindle, tapping round the hole at the outer end to draw them out, in this case also patience is generally found better than force.

The same remarks apply if the link is hung in the SECOND manner mentioned, with weigh-shaft below, except that the engine would be put into fore-gear to get out the quadrant block pin, as the swing links would make it impossible for them to pass in back gear.

All the motion in this design is upon the driving axle side, or behind the motion plate, so that the crossheads are not likely to be in the way of getting out any part of the valve gear, but in some cases they also have to be considered.

The THIRD method of hanging the link is shown at B, and if the defect is not in any part of the valve motion itself the quadrant block can be taken out, for the link has a long slot in which it can freely move without fouling the ends of it. It will be necessary to carefully watch when the swing links are out of the way of the pin which has to be drawn out of the quadrant block, and as the position of the weigh-shaft and length of swing links vary so considerably when hung in this way it is not possible to give any definite position for setting the engine to remove this pin. In the example drawn, however, as the links are attached to the intermediate valve spindle, which in this case also swings between the slide bars and upon the cylinder side of the motion plate, the crossheads must be watched, or it will not be possible to draw the pins out if these are in the way.

If it is found necessary to take down the rods, the same position of the cranks, the 8th, when both cranks are upon the top quarters, will be found the most convenient to take out the eccentric strap bolts.

In the FOURTH design, as illustrated at C, the motion plate is carried forward to the centre of the slide bars, so that the crosshead has to be out of the way of drawing the pin through the quadrant block, the rest of the motion may, as in the last example, be left up, as a long slot is provided in the end of the intermediate valve spindle, which in this case works through a guide fixed to the motion plate.

In both the last mentioned cases it sometimes greatly facilitates the getting out of the quadrant block pin, to uncouple the swing links at the quadrant link end first and swing them clear until the quadrant block is removed, and then couple up as before. This is especially the case when the engine cannot be moved in order to get the link in such a position that the swing links do not cover the pin.

It is extremely improbable that all the nuts upon the bolts through the eccentric straps can be taken off by means of spanners, especially if the engine cannot be moved to place them in good positions, it may happen, therefore, that the hammer and chisel will have to be resorted to, to slacken them.

In the case of other link motions, such as Allan's or Gooch's, the radius rods, from the crosshead upon the valve spindle to the quadrant block can be taken down or the quadrant block removed in order to put them out of action. If it is found necessary to take down one side entirely, the eccentric rods, bolts and nuts must be taken out in the same way as above described, and the valve placed centrally and locked by the gland.

When Joy's radial gear is fitted there are no eccentrics to be dealt with, and the easiest way to disconnect is to uncouple the radius rod from the crosshead upon the valve spindle, and swing that end of it up out of the way by means of a piece of rope to the handrail or other convenient fixture.

If it should be necessary to take down one side entirely, it can be done by removing the pin in the radius rod above mentioned, the pin through the connecting rod, and correcting link, and that at the fixed end of the anchor link below, then if the motion is put into foregear, so that the slipper in the curved guides can slip out, the whole of the side to be disconnected will fall to the ground, and can there be further taken to pieces, picked up as one, or left, as determined by circumstances.

After closing the valve and locking it, the next steps in the uncoupling of the engine are to get down the connecting rod upon the defective side and to fix the piston in a safe position.

It will be assumed that the engine being operated upon has motion of the single bar type, with box cross-head, small end pin with a nut upon the end of it, and a solid eye to the small end of the connecting rod, which has a "big end" of the common strapped form, with two brasses held in position by a strap passing round them and secured at top and bottom of the butt end of the rod by two long bolts with two nuts at the bottom of each, the brasses being further held and adjusted by a long cotter.

If the defect, necessitating the disconnecting, is such that the engine can be moved and placed in any position so that the bolts, etc., upon both ends of the connecting rod can be brought into convenient places, the small end pin should be slackened, the nut upon it being turned so that it can be easily taken off by hand, and the pin itself knocked back a little and made ready for removal. The "big end" bolts should next have the nuts taken off, first removing the cotters or split-pins, and the bolts slackened by giving them a blow fairly upon their small or bottom ends, as they are made taper to be easily taken out; one may be removed altogether, but the other should be left in position for a time. The two set screws securing the long cotter in position, and the split-cotter through the bottom end of it having been meanwhile removed, the cotter itself should next be slackened, but not taken out.

It will usually be found that the most handy place for uncoupling the "big end" is either upon the front-centre or the bottom front quarter, as then the nuts upon the long bolts are farther from the cheeks of the cranks than in any other position ; if placed, however, on the centre, it should be ascertained whether it is possible to get the bolts out, as the height of the boiler may make it impossible for them to pass when the cranks are in this position. In some engines when the crosshead is towards the back-end of the stroke, the small end-pin cannot be drawn out owing to the valve-spindle guide and the motion-plate ; this also should be noted before commencing to take the parts to pieces.

The whole of the holding-gear being now in a slack condition, a piece of rope which can be secured to the handrail or other convenient fitting, should be passed down from above and tied to the big end of the rod to support it whilst the "big end" strap is being removed. The "big end" bolts may both be removed, and if the crosshead is pinched forwards it will draw the rod out of the fork of the "big end" strap, and it can then be either held by the rope, or lowered into the loop of the motion-plate, as found most convenient. The "small end" pin should next be taken out to allow the rod to be removed entirely ; it can be lowered to the ground by means of the rope, and then picked up and secured to the foot-plate for removal with the engine.

The long cotter securing the brasses in the "big end" being taken out allows the glut-plate and front-brass to fall out, and on turning the strap up so that the fork-ends point upwards, it and the other brass in it will fall off and leave the crank-pin free. The strap should have the two brasses, glut-plate, long cotter and bolts replaced in their respective positions, and the whole secured to the rod.

It should be noted that in many engines it is not possible to get the brasses out of the "big end" straps until the set-screws holding the long cotter have both been entirely removed, as they will not allow the former to pass; it is, therefore, best to see that this is done before the cotter is removed. Further, as the cheeks of the cranks will not permit the set-screws to come out in most positions, it will be found best generally to remove them as soon as they are clear while setting the engine for getting out the other bolts, etc.

The crosshead should next be moved until the piston is at the extreme end of the cylinder, and secured there by locking the gland upon the piston-rod, and also by means of clips, when these are carried upon the engine, secured by bolts to the slide-bar to prevent the crosshead moving.

The cylinder cock gear upon the defective side should be uncoupled and the cocks opened, so that, if by any chance the valve should allow steam to pass this may not accumulate behind the piston and render it liable to be forced to the other end of the cylinder and cause damage.

There are differences of opinion as to which end of the cylinder the piston should be secured; but all things considered it is usually best to fix it at the back end, as then the glands can be easily got at to lock the piston-rod, and also if the steam does happen to move the piston it will be forced to the front end, and damage here is not nearly so serious as it would be to the back end owing to there being no attachments, slide-bars, etc., fixed to it, only a plain cover, and this, if broken, can be easily replaced.

In the case of engines having four slide-bars and a fixed pin connecting the slide-blocks, there will necessarily be a strapped small end, and the mode of proceeding to uncouple will be the same as already described for the big end, excepting that it is not, as a rule, essential to take the strap and brasses off the pin, but simply release the rod by taking out the bolts and leave the remainder in place, putting back the bolts in their respective holes, and replacing the nuts after the rod has been taken out.

In the above it has been assumed that the engine can be put into convenient situations, but this is not always the case. Very often, indeed, it is immovable in a particular position, and that one in which it is not easy to get at the "big end" bolts, as would be the case if the crank was upon the top back quarter or any position near to it, then it would be almost impossible, with the tools usually carried upon a locomotive, to get any of the nuts off. When this occurs so, uncouple the "small end" and drop it into the loop of the motion plate where it will safely ride whilst the engine is pushed along to get the bolts more accessible.

It may by chance happen that the engine gets set in such a position that neither end can be uncoupled; if this happens the breakdown must be looked upon as a complete failure, and proceedings taken as in the case of a broken crank axle, to be detailed later.

The most common failures that would render uncoupling necessary are broken piston heads or rods, often due to the presence of water in the cylinders, broken or bent connecting rods, broken straps, broken crossheads, etc.; it does not follow, however, that any of these occurring will make disconnecting absolutely essential. For instance, if the piston rod broke through the cotter hole at the crosshead end, the piston being driven forward with sufficient effort to break the front cover and become firmly jammed there, as is very likely to be the case if the crosshead was of the single bar type, it would not foul anything. All that would be necessary to be done in this case would be to close the valve, if any long distance has to be travelled to the shed in steam, or let the whole remain if there is only a short space intervening; of course, in this latter case there would be a great loss of steam with considerable noise as it escapes through the broken front end.

If the crosshead is of the four bar type, or any other that has a loose centre that would drop when the piston rod is removed, it would in most cases be necessary to take down the connecting rod as it would be likely to foul the motion plate if it were left in position.

It is usually best to uncouple for a broken piston head, as the broken and detached pieces may work through the ports, and the slide valve fouling them will cause a much more serious failure; pieces may also get between that part that remains on the rod and the ends of the cylinder, and do further damage. Generally speaking, however, the boss of the piston pulls out of the disc, which remains otherwise intact or breaks up into several small pieces; as it is impossible to ascertain this for certain by casual observation, it is best to uncouple at once.

A broken connecting rod, if at the "small end," will render disconnecting necessary, excepting in a few cases where the motion plate is situated well back towards the crank, so that the rod will safely ride in the loop of it, when it can be left up; as the risk of catching in the plate and doing serious damage is great, however, this is not recommended.

When the "BIG END" STRAP OR THE ROD itself near to it gives way as the piston is moving towards the front end, the small end of the rod will then remain connected to the small end pin, and will generally safely lodge in the motion plate, a piece of wood wedged between the back of the crosshead and the motion plate adds to the security in preventing the former from moving. The "big end" and strap will have to be taken off the crank pin, as they would, it left up, be liable to damage the front of the firebox or under side of the boiler ; the valve in this case should be shut.

When working with one side of the engine only drivers should carefully see that they do not stop with the working crank upon its dead centre, as then it will not be possible to start again with steam without resorting to pinch bars under the wheels to commence movement, which is, to say the least of it, a very troublesome proceeding.

One Broken Coupling Rod will necessitate the taking down of both in all cases, because if one rod is left up and the driving wheels happened to slip, a severe strain would be thrown on it and the crank pins, or when the crank pin upon the second wheel of the one pair was upon either its front or back centre, there would be no turning effect transmitted, and the rod and crank pins would be liable to breakage.

It is not desirable, in all cases, to take down the coupling rods when the connecting rod upon one side has been disconnected, for by doing this the engine is partially unbalanced, and therefore will not run so easily as it would do if they were left up, and more power would be required to move it.

Breakage of Coupling Rods in service will generally be found to be at or near the centre of their length, whilst failures of the crank pins usually occur when the engine is starting a train.

If the engine has four wheels coupled, and a rod or pin breaks, both rods will have to be removed, and the engine worked as a single driver, but if it has six or more wheels coupled together, there are always joints in the rods, either in the leading or trailing length, or at the driving journal, to allow of the necessary vertical flexibility, and whichever length of the rod breaks it must be taken down as well as the corresponding length upon the other side, and the engine worked as a four coupled.

If the rods are jointed in the leading length, and the leading crank pin, or the leading length of rod breaks, it will be necsssary to take down the leading length upon the other side of the engine, uncoupling at the joint, but if the trailing length or driving or trailing crank pin broke, the whole of the rods upon each side must come down.

When, however, the joint is in the trailing length, it will be exactly the reverse, and a defect to the trailing end will necessitate uncoupling the trailing wheels only, whilst one to the leading end will disable the whole. When the bush on the driving crank pin forms the knuckle joint, it is usually forced into the rod end by hydraulic pressure, and it is not possible for drivers to remove it; in such the whole of the rods will have to come down for any failure.

It is not always necessary to give up a train, when the engine has to be uncoupled, for with a moderate load it can usually be worked on, at least to a station where a change of engines can be arranged.

Putting sand, or allowing it to run, upon only one rail as the engine is starting a train or slipping, is often the cause of bent or broken side rods, as it puts very unequal strains upon them.

A Broken or Lost Spring will usually make it necessary to give up a train, as it is not safe to run at speed under these circumstances, but it depends upon the position of the defect as to whether the engine is unable to run at all, or not; for instance, if the axle that has a lost spring is one which has four bearings upon it, and one of the inside springs was defective, as most engines carry less weight upon the inside spring it would not necessitate giving up the train, whereas failure to one of the outside springs would be more serious.

If a spring upon an engine with only two bearings upon each axle, breaks or is lost, it will be necessary to stop running and get into a siding, where no delay will be caused to traffic, and by means of a jack placed under the buffer beam or frame, lift up the defective part until the distance from the top of the axlebox is an equal distance from the hornblock to that upon the other side of the engine then, a distance piece having been put in to keep it so, it will be safe to move the engine slowly home, or to some place where a new spring can be secured.

When it is found necessary to lift up one end of the engine in this way, the jack is first taken to the opposite end of the engine, and placed under a convenient part of the frame, the weight of the engine is next taken and distance pieces put between the top of the boxes and the hornblocks, after which the jack is put under the opposite end and the lifting more easily performed than if no blocks were placed at the other end to form a fulcrum; the lifting at one end, without taking this precaution, will be a much longer job, since the engine will settle upon the springs at the other end and necessitate a lift of double the distance before the weight of the engine is taken up.

The Breakage of an Axle in service will, in most cases, cause a complete failure, though occasionally it may be possible to work home. Assuming that the leading axle of a six-wheeled engine has broken, it will be necessary to telegraph for the breakdown van and a trolly; on arrival, the latter will be placed under the leading end to keep the weight of the engine from the defective axle altogether. Blocks should be placed between the bottom of the axle boxes and the hornstays, before the lifting on to the temporary truck or trolly is performed, so that the disabled wheels and axle may be raised with the framing of the engine, until they are clear of the rails, in this condition the engine may be safely drawn home to have its defects remedied.

The foregoing remarks will also apply in the case of the trailing wheels of a six-wheeled engine.

The method of procedure with a broken crank axle on an engine of this type would be somewhat as follows: first take down the coupling rods, and then uncouple the driving springs on both sides by removing the centre pins, taking care to ascertain beforehand whether the springs are hung by links at the ends; in some engines they only press upon wearing plates, and the removal of the centre pin will allow them to fall together, and then if the operators are not prepared for this they are liable to injury. In order to remove the centre pin proceed as before suggested, place distance pieces between the top of the axle boxes at one end of the engine, and then lift at the other end on the fulcrum so made, until the weight is raised from the driving spring when the pins at the centre can be knocked out: turning the pins half round in the holes will often make the removal easier; unless this is done, the shoulders which may have become worn on them will catch at the edges.

When lowered, the engine will rest upon the leading and trailing wheels alone, their own weight and that of the driving axle only remaining on the driving wheels. When the engine is down on the rails, remove the distance-pieces first mentioned, and take the jack to the driving wheels and lift them up clear of the rails altogether, placing blocks between the bottom of the axle-boxes and the horn-stays for them to ride on. This lifting can be done either by lifting the wheels and axle as a whole, by going beneath and placing the jack under the centre of the axle, or it can often be best done by putting the jack under the outside of the boss of the wheel, or, below the crank-pin on one side, and when that is blocked up safely go to the other side and treat it in a similar way; either of these methods can be followed according to the build of the engine, and accessibility of the various parts concerned.

In the case of an engine which has leading and trailing carrying wheels, with four-coupled wheels in the centre, the end-wheels would have to be treated as described, and also the driving wheels, but the intermediate wheels could be put out of action by being lifted in a similar way to the drivers, taking off the rods and lifting the wheels clear of the rails; the engine could then work home in steam if it was necessary or desirable to do so.

Broken Tyres can be treated in a similar way to defective axles, but this depends to a certain extent upon the method adopted for fastening them to the wheels; when studs through the rim are used, they will often be broken by the tyre springing open when fractured, and are then unsafe, but if rings with lips projecting into recesses in the tyre and wheel rim are employed they are much safer and will hold the tyre to its place even if it is broken. In any case it is not advisable to work a train with fractured tyres on the engine.

A Broken Eccentric Strap, should it be one of the back-gear straps and the engine is running forwards, will not always necessitate the taking down of the fore-gear strap on the same side, but the defective strap and rod only. It will be quite safe then to run in fore gear; the beats will not, however, be true, the valve movements being very erratic owing to being coupled up at one end only. If it should be necessary to reverse the engine and run backwards it can still be done without uncoupling, but as the eccentric rod actuating the valve will be at the top of the link and out of action, movement will not be communicated to the valve at all on the majority of engines, and this will simply remain stationary. It will be necessary to see that the valve, which has only a fore-gear rod coupled to it, is in its central position, so that the ports upon that side may be shut; care should also be used to avoid stopping with the crank upon the other side on either its front or back centre, for then the engine will be unable to start when required.

Failures to the Fore-Gear Rod or Strap may be dealt with in a similar way, that is, if the engine is working in back-gear with the fore-gear rod removed. Both valves will operate but with irregular beats, and if the engine is reversed into fore-gear, the valve upon the defective side must be placed centrally, and the engine worked on one side only as above described.

It is not advisable to run fast with an engine in the above condition, as the fork of the eccentric rod as well as the quadrant link is liable to be damaged and a low speed should therefore be maintained. If the defect is such as to make it advisable to take down both eccentric straps and close the valve, it will not be necessary to remove the connecting rod on that side, but the cylinder should have plenty of lubrication as it will be running dry whilst no steam is admitted to it.

Shifting Eccentric Sheaves when required to be refastened can be secured by means of the set screws which are usually provided to assist the keys in holding them in position on the axle. When no set screws are employed there are no means by which a shifted sheave can be temporarily refixed and the gear upon that side had better be taken down and the valve closed; the connecting rod can remain up as before.

Failure of the Quadrant Link will necessitate taking down both the eccentric rods connected to it and closing the valve. If one of the suspension links supporting the quadrant link breaks, or as is more common, especially in those engines which have but one support to each link, the saddle pin upon the quadrant link siezes and breaks off, it can be left if the engine does not have to travel fast; if it does and it is necessary to notch up, it will be best before starting the engine to lift the link upon the defective side into about its running position. This can be found by putting the lever into the pre-arranged position and measuring the distance between the top of the quadrant block and the quadrant link upon the unaffected side, and then putting the one to be secured into a similar position, placing a piece of wood of the required thickness between the block and link, so that the cut-off shall be correct in running. When starting the train, which should only be attempted when delay would be caused by giving it up, the lever must be put into full gear. Then, of course, as only one side is coupled to it, the engine will give two heavy beats and two light ones per revolution, but when the lever is moved into its running position the engine will beat "square."

If it is necessary to reverse and run backwards with an engine crippled in this manner the link must be lifted up still higher, and a longer distance piece inserted between the quadrant block and link, and kept in as long as it is required to run backwards.

A Broken Arm upon the Reversing Shaft supporting either link will require similar treatment to above, but if the arm breaks which is connected to the reversing rod, and upon which both sides depend, then both quadrant links will have to be otherwise supported in their required positions. This can be done if the shaft is fitted with adjustable bearings at the ends by tightening up the caps of these, and so holding the shaft. If necessary one cap can be slacked back and a piece of tin or other convenient substance inserted and the cap screwed up so that the shaft may be gripped and held. A broken reversing rod requires a similar remedy.

Should the Reversing Shaft Seize in its bearings, or any other defect happen to the controlling gear so that it becomes immovable, the engine can be reversed by uncoupling the suspension links at the ends connected to the arms of the reversing shaft, and raising or lowering the quadrant links into their required position, and securing these there by means of blocks of wood in the links as before described.

A Broken Valve Spindle, if outside the gland, will render necessary the uncoupling of the valve gear either by taking down both eccentric rods or by removing the quadrant blocks as described earlier, the valve can then be secured in its central position by causing the gland to grip the broken spindle. If the fracture is inside the steam chest and the spindle is carried through the front cover and fitted with a gland there, this may be utilized for the same purpose, and the valve will be secured. But on engines having no front spindles the valve cannot be held safely without taking off the cover of the steam chest and wedging the valve in the required position. This procedure is especially necessary on those engines having the two valves working back to back in a common steam chest between the cylinders, as the disconnected valve not being held in any way to its face would be likely to get between the working one and the steam chest cover, and so cause serious trouble. Except in those cases where time is of little moment, it will be usually best to consider a valve spindle broken inside the steam chest a complete failure, unless the engine has separate steam chests where, of course, there is no fear of the perfect valve catching the defective one. In the other contingency the steam acting upon the back of the loose valve may keep it to its face, and thus close all the ports. Whilst it does this it will be good policy not to close the regulator so that the steam chest may be kept full of steam and the valve kept up, the engine being stopped by reversing the gear and applying the brakes.

If the slide valve has a badly Broken Lap and it is necessary to disconnect the valve gear, after the rods are removed, put the defective valve in such a position that it covers the exhaust and one steam port, leaving the other open. The cylinder cocks must be used to test when the closed port is tight by opening them and admitting a little steam to the steam chest. In this class of mishap it is necessary to uncouple the connecting rod upon the defective side and take it down, pushing the piston to the end of the cylinder and fixing it there. Care should be taken to fix the piston at the opposite end of the cylinder to the open port, as steam will have free access to the cylinder at that end, and if the piston were by any chance left there, it would probably be projected with great force to the other end of the cylinder and cause breakage.

If instead of the lap the CROWN OR CAVITY of the valve is broken nothing can be done, and a complete failure must be reported. The engine will have to be drawn home by another, for any steam admitted to the steam chest would have a direct outlet to the exhaust port and blast pipe through the broken valve.

TOOLS—Having so far dealt with most of the defects and breakdowns which are liable to occur in running, a few words will be said upon the tools carried upon an engine.

Every driver should see that he has the full complement of tools upon his engine before leaving the shed. The equipment varies on different railways, but there should certainly be spanners of such sizes to fit all the nuts and bolts of the motion. When a suitable opportunity occurs and the engine is standing over a pit, it will not be lost time for the engineman to try his spanners over these nuts, so that the proper implements to do any uncoupling work may be readily selected when the necessity suddenly arises.

The practice of selecting the handiest tools will also help to locate the best places in which to set the engine for working upon it when taking down, or securing any defective part.

In addition to the regular tools supplied it is a good principle to take a few extra things. The pocket knife every engineman should carry should have a good stout blade well sharpened as it will be found useful in cutting the pieces of wood required for some of the remedies outlined. A few pieces of wood of handy size, say 1-in. square by 6-in. long, will often come in useful. As an instance of the convenience of such we might note that if the cylinder cocks happened to catch some obstruction on the line left by platelayers and were broken off, a piece sharpened at one end can be driven into the hole left by the cock to prevent the escape of steam, a very necessary precaution when such a mishap arises, as unless the hole is stopped up the steam blowing down on to the ballast will throw it up into the motion, and soon entirely disable the engine.

Half a dozen pieces of hardwood (say 2-in. square by 6-in. long) will do for packing up the axleboxes or quadrant links if any of the defects mentioned arise, but, if these are not carried, rail keys may be found to answer. Slide bar clips should be provided, but if not, one or two pieces of wood about 3-in. square and long enough to fit between the crosshead and cylinder on the motion plate should be carried so as to secure the crosshead if required when uncoupled.

Some rope or spun yarn and a piece of india-rubber insertion for temporarily making a joint or stopping a troublesome blow, and a few blank washers of copper or tin will often be found useful, as also will a few $\frac{3}{4}$-in. bolts from 2-in. to 1-ft. long, with a selection of washers of various sizes.

Taper or split pins to fit the motion, etc., should never be omitted from the tool box, nor a piece of copper wire and a pricker of about $\frac{3}{16}$ in. diameter by about 1-ft. long pointed at one end for cleaning out oil holes, etc.

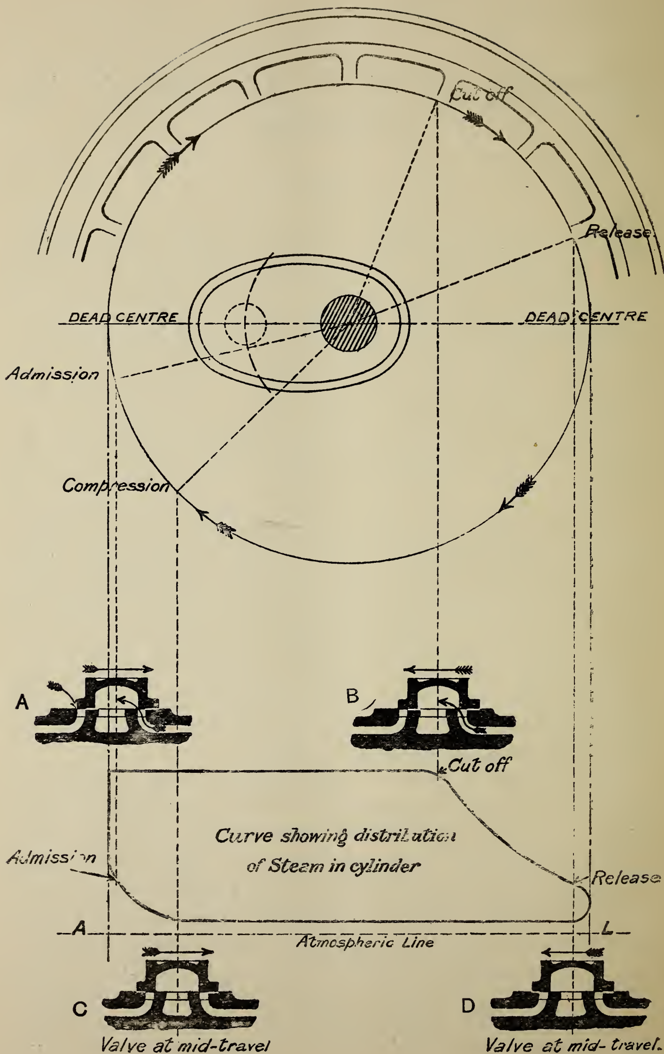
EXPANSION OF STEAM AND WORK IN THE CYLINDERS.

HIGH pressure steam, not in contact with water, possesses certain properties of expansion which are defined by well-known natural laws, and to economise in its consumption in the cylinders these features have been utilised to secure maximum service from any determined volume of steam taken

The diagram on the following page shows in an elementary manner the "cycle of work" in a cylinder of a locomotive during one stroke of the piston.

The circle represents one revolution of the driving wheel, and the crank is to be seen inside this. On the circle is marked the position the slide valve occupies at corresponding points in the stroke of the piston; the vertical projecting lines connect these with the diagram below, which illustrates by its area the amount of useful work performed by the steam admitted to the cylinder during two-thirds of the complete stroke of the piston.

Commencing with "admission," the point at which steam is allowed to enter the cylinder just before the crank reaches its "dead centre." the valve will occupy the position A. The valve continues to move and open the port until mid-travel is arrived at, when it returns and cuts off the admission of steam at the determined point marked (in this case about 66 per cent. or two-thirds of the stroke) B. The steam imprisoned in the cylinder continues to drive the piston by virtue of its ability to expand, and still exerts considerable effective


Cut off
Release
DEAD CENTRE
DEAD CENTRE
Admission
Compression
A
B
Cut off
Curve showing distribution
of Steam in cylinder
Admission
Release
A
L
Atmospheric Line
C
D
Valve at mid-travel
Valve at mid-travel.

pressure when the point of release is reached; here the valve opens to exhaust, and the cylinder is emptied by the return stroke of the piston. The "back pressure" or resistance to movement of the piston is shown by the base line of the diagram immediately above the atmospheric line drawn to illustrate the condition of affairs which would exist if the cylinder had its end open to the atmosphere. C and D show the position of the valve at mid-travel.

LUBRICATING, CARE OF CYLINDERS, ENGINE, &c.

THE proper LUBRICATION of the various running parts of a locomotive is of paramount importance, and, as the cause of many failures and delays is to be directly traced to a want of care or knowledge of the subject, it is desirable it should receive due attention on the part of those concerned.

To reduce the friction between any moving bodies in contact some lubricating substance is required, if this is not supplied and the faces run dry, a considerable generation of heat will result, expanding the different parts in all directions until either the softer metals used in the construction are melted, or the harder ones become attached to each other or, as more commonly expressed, "sieze." Should this occur to any large member, such as an axlebox, it will doubtless cause a stoppage until the defect is remedied. With the smaller parts—pins, etc.—breakage will occur, and awkward results may ensue. As an instance, the saddle pin on the side of the quadrant link might "sieze" and break off, allowing the link to drop down into full foregear.

When oil is introduced as a LUBRICANT it forms a thin film between the faces of the moving parts rubbing on each other, and prevents the metals of which they are composed from actually touching. The quality of oil for use as a lubricant depends upon its power to form this film, and one that will remain longest without being squeezed out is the best; this property can only be satisfactorily demonstrated by tests in a suitable machine.

Two kinds of oil are usually supplied for locomotives, one for the machinery, motion, axleboxes, etc., and the other for the slide valves and pistons.

For the first a mixture of vegetable and mineral oils is commonly employed, the composition being varied for the different seasons of the year. Rape oil is considered a good lubricant for this purpose. but if used alone is expensive, hence the more general adoption of petroleum oils. For the second purpose, mineral oils will stand much higher temperatures than either vegetable or animal, and the adoption of higher pressures of steam has practically made the employment of heavy petroleum oils for the lubrication of valves and valves and pistons all but universal. Should rape oil or tallow be used the ports and steam channels will be found to become coated with a thick hard deposit, which must be periodically burnt off or the passages will become too small to allow the necessary steam to pass for maintaining the efficiency of the engine. With MINERAL OIL this trouble occurs to a less extent, as it is only when the engine is running with the regulator shut and the reversing lever in opposite gear that such oil will be vaporised by the hot gases drawn into the steam chest from the smokebox.

Many enginemen still express their belief in the employment of TALLOW as the best lubricant for the cylinders. This may be partly due to its solid appearance and nature when cold, which leads to the impression that it will remain longer to act as a lubricating medium in the steam chest and cylinders. A little consideration, however, will prove the fallacy of this reasoning, as it will be observed that if tallow is put into a kettle and this is placed upon the ledge over the firehole door the tallow will melt and will form a liquid less viscous than the rape oil, and considerably more volatile.

A little tallow put into oil cups or axleboxes will often be beneficial, as it will mix with the oil and thicken it so that it will not syphon out so fast, but this must be done sparingly, otherwise the oil may be thickened to such an extent that the trimmings will not act, and heated bearings will result.

GRAPHITE or BLACKLEAD is also open to a similar objection: used moderately it is beneficial, but it has a tendency to cause the parts upon which it has been used to rust, and therefore when an engine on which blacklead has been employed is about to be laid off, the surfaces should be well greased.

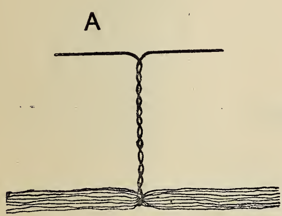
The OIL CUPS provided at the various points where lubrication is required are either forged or cast upon the bearings, etc., or made separate and screwed in. These should be large enough to hold sufficient oil for the longest trip that the engine is likely to make.

The TRIMMINGS for these cups are usually made of worsted, held by means of copper wire, and are formed in various ways. Two kinds are used, called respectively "plug" and "tail" trimmings, the worsted in the former being made long enough for the ends to come nearly level with the top of the syphon pipe standing up in the cup, whilst the worsted in the other kind is left long enough to reach over the top of the pipe down to the bottom of the oil well, whence it lifts the oil by capillary attraction into the pipe, and thus gives delivery to the wearing surface.

PLUG TRIMMINGS are used on all those parts of the engine having reciprocating or rotary motion as their movement whilst running will be sufficient to agitate the oil in the cup, and lift its surface to enable some to pass the trimming by percolation to the bearing.

All the other parts of the engine that have no independent movement apart from the running, such as axleboxes, slide bars, glands, etc., will require tail trimmings, as there is no motion sufficient to lift the oil to the level of the tops of the syphon pipes.

The distance from the top of the oil pipe to the bearing will determine the length of the wire and worsted forming the trimmings, and to ascertain this a piece of wire should be inserted into the hole in the latter, its length taken and the trimming made about $\frac{1}{2}$ an inch shorter than this, so that the bottom of the wire will clear the journal. The quantity of worsted required will depend upon the size of the oil hole, consistency of the oil to be used, and the amount of movement that the part receives, as, for instance, the big end plug will require to be a thicker one than that made for the small end, if the holes are of a similar size, as the amount of movement is so different. The exact size depends so much upon the oil used and the work that the engine has to do that it is impossible to give a more



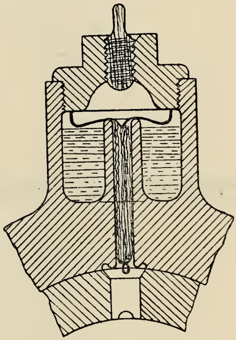


Fig. 10.

definite rule for this, and it must therefore be left to experience gained from actual trial. Note should be taken of the number of strands used whenever a new trimming is made, so that when the most satisfactory size is found it can always be worked to. Trimmings may then be made and kept in readiness to replace any of those in service, so that should it suddenly be found necessary to renew one no delay or anxiety will be caused as to the working of the new one.

All wick trimmings require to be occasionally removed, wiped and replaced. There will then be no uncertainty as to their satisfactory working.

In Fig. 10 one method of making a plug trimming suitable for the lubrication of a coupling rod is drawn. A piece of copper wire is cut off of a suitable length and bent at the centre to encompass the desired number of strands of worsted of the necessary length. These are secured by twisting the wire to form a stem long enough to reach to the required depth in the oil tube, the upper ends of the wire being spread out as at A. The cap of the oil cup is unscrewed and the trimming inserted in the

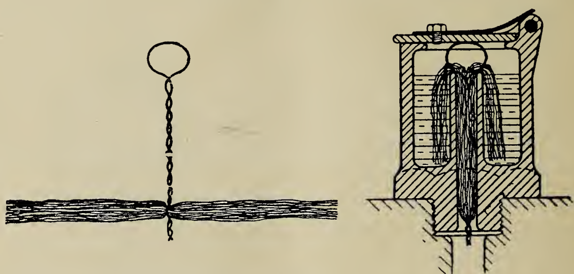


FIG. 11.

pipe until the fork of the wire rests upon the top of the syphon pipe, and so prevents the trimming from working down when the engine is running. The extreme ends of the wire can be given an upward bend, so that when the cap is put on it bears upon them and holds the trimming firm. There is a slight recess left in the top ot the oil pipe by making the trimming a little short, and into this the oil is thrown at each revolution of the crank pin when the engine is running; of course no oil will be used when it is standing.

A Piece of Cane or Cork is screwed into the hole in the cap, and this being slightly porous allows the slow admission of air to the cup to replace the oil used. In cups with a spring button instead of the cane a small hole is usually drilled through the button for the same purpose.

A tail trimming for stationary oil caps is illustrated at Fig. 11. The wick is in this case secured by the copper wire in a slightly different way. The

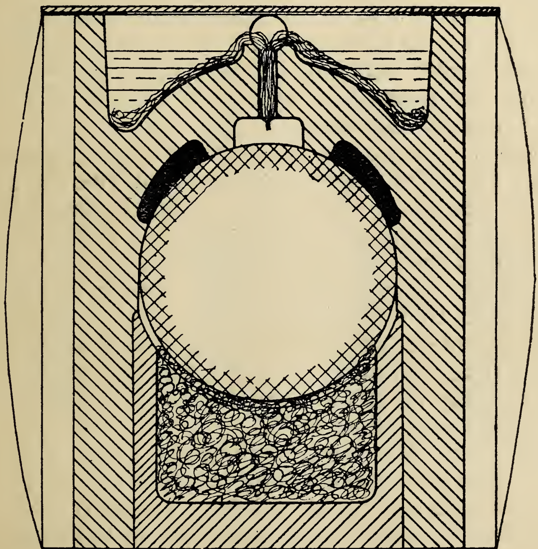


Fig. 12.

wire is cut off and bent over to form a loop, and the twist continued until it is sufficiently long to reach to about $\frac{3}{4}$ of an inch from the bearing. Here it takes the worsted, which is secured by about two or three more turns of the wire; it will then be as shown at the left. The loop formed at the top then acts in the oil cup exactly as the spread ends in the last example, and forms a convenient means for withdrawing the wick when necessary, The tails are made just long enough to reach to the bottom of the cup; more than this is not desirable, as it would only take take up room required for oil.

A Trimming for an Axlebox is made in a similar way, but the tails are left much longer, as the oil receptacle is larger and shallower, and so the worsted must spread out more to come in contact with the oil. In the keep below the journal either a pad of horsehair and waste or sponge is put. This is to collect the oil that works down and prevent it from being lost, and as the pad presses against the journal it well oils it as it revolves. Both these are illustrated in Fig. 12.

Another neat way of making a trimming is shown at Fig. 13. The copper wire is first twisted as at A, then strands of worsted are passed round it as shown at B, until the required size is obtained, the two ends of the worsted being left at the top. The copper wire is given two or three twists at the top and bottom to firmly secure the worsted, and the two ends are cut off flush, as at C, if it is desired to make a plug trimming; but if a tail one is required the ends may be left a little longer to reach down and form a syphon as at D.

Instead of the wick trimmings some engines have a bent pin which hangs over the top of the oil pipe and collects the oil as the cup moves about, and allows it to fall down the pipe to the bearing. Others have a screw plug through the top cover, forming a valve to close the oil pipe; the amount that this plug is screwed up is the opening allowed for the oil to pass and collect on the plug, from which it drops down the oil pipe, as in the last case.

When examining a locomotive both before and after a trip, particular attention should be given to the oil cups, to see that none of the covers or the cups themselves that are screwed in the various parts are loose; the latter if not tight are liable to come out and be lost, or by getting into the moving parts of the engine cause damage. The cups should be periodically cleaned out, all dirt and deposit being removed, as this not only helps to spoil the oil, but takes up room which should be occupied by it.

LUBRICATION OF THE SLIDE VALVES AND PISTONS is effected by different forms of lubricators working under steam pressure, and each of these will have special points for the engineman's attention. In the Roscoe or "displacement" lubricator, largely employed for the steam chests, the delivery

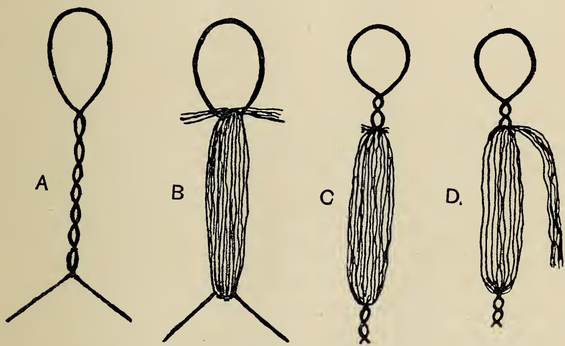


FIG. 13.

of oil is regulated by means of a small screw valve provided at the passage which forms both steam inlet and oil outlet; the condensed water is drawn off from the valve at the bottom of the lubricator and fresh oil is introduced through the filling hole at the top. When charging this form of lubricator care should be taken to avoid filling the reservoir too full or there is a possibility of it refusing to act; the best test of its working is to open the draw-off cock and ascertain if water or oil issues; if the latter, then the lubricator cannot be working properly, for no condensation of steam and consequent displacement of oil has taken place; reduction of the quantity of oil in the reservoir will probably put matters right if no more serious reason for inaction exists. In very cold and frosty weather it may be desirable to protect the lubricator, if placed in a very exposed position, by wrapping it in sacking or spun yarn, or housing it in wood; the cause of its non-operation at these times may be found in the fact that the steam is condensed in the branch pipe before it enters the lubricator body and runs back down the pipe to the steam-chest in the form of water; further, the oil may become congealed by the intense cold forming a mass too thick for the water to penetrate; in either case, warming the lubricator body will probably enable the circulation to commence and so overcome the difficulty.

The "suction" type of lubricator used for the pistons will not be found to work properly if allowed to get too hot. It is liable to this failure when fitted to the front cylinder covers with a flap to close them in; raising the flap to allow a circulation of air for cooling will restore the proper feeding of oil. When fitted to the back covers these lubricators will supply oil for the piston rods as well as the pistons, and they are best placed if attached to the frames with connecting pipes to deliver the oil to the cylinders.

On engines of recent construction the lubrication of both valves and pistons is effected by sight feed lubricators conveniently placed in the cab, in these the oil is displaced by the condensation of a small steam supply, and some of the remarks on the working of the "Roscoe" lubricator equally apply. Each make of "sight feed" may have its peculiarities, and therefore it is only possible to point out a few of the chief and characteristic faults and failures. There are very few of these devices which are not more or less affected by the opening and closing of the regulator, and it might be here stated that the one which is least influenced in this respect is the one which lends itself most to the engineman's favour, for nothing can be more exasperating than a continual rushing to the lubricator to shut it down and prevent the oil "running away" every time the regulator is closed. An important detail in this control of the flow of oil is to be found in the small nipple usually placed in the delivery pipe at its outer extremity, and when a particular "sight feed" developes a sudden propensity to allow the oil to "run away" after it has been in service some time working regularly and without trouble, an examination of this passage should be made, and if found worn and enlarged it should be replaced by a new and finer nipple.

When a double sight-feed lubricator is used its mode of working is precisely similar, but it has two regulators, sight glasses, etc.; one of these usually supplies oil to the steam chest, and the other oil to the cylinders, the lubricator often being marked to this effect, so that the enginemen may know where it is delivering oil. The sight glass nearest the weather board is usually the one selected for the steam chest, as it is less liable to be affected by the weather in this position, especially when the engine is required to run backwards; there is, however, no rule as to this, and when an engineman has a doubt as to the part each feeds, a good way of settling the matter will be to close the regulating valves on the lubricator, and to uncouple one of the pipes at its connection to the cylinders or steam chest, and watch this whilst the fireman slightly opens one of the regulating valves of the lubricator; if oil issues from the pipe uncoupled it indicates that the valve opened controls the supply to this point.

When running with steam on, the steam chest should have more oil, but when running with steam shut off the cylinders require the greater quantity, except in those designs of engines which have the slide valves on top of the cylinders. When the slides are between the cylinders, or below them, they drop from the faces when steam is shut off, and require no lubrication.

No more oil should be supplied in any case than is absolutely necessary, as it is only required to cover the working faces with a thin layer; all in excess of this is waste, as it is either blown out of the blast pipe with the exhaust steam, or clogs in the steam passages and helps to block them up, as has been mentioned before.

According to some authorities from two to four drops per minute should be sufficient for engines with cylinders from 16 to 18-in. diameter by 24-in. stroke, with larger cylinders five to six drops per minute may be required; from this it may be assumed that the quantity often passed by a sight feed lubricator is somewhat excessive.

As to care of the lubricator itself, it should not be allowed to get either too cold or too hot, as it may refuse to work in either case, it should be thoroughly cleaned out, say at three months' intervals, by emptying the reservoir and filling it up with paraffin oil, letting this stand for a time to allow of the "gummy" deposits left by the oil being dissolved and run out. The filling valve should be closed, and steam blown through the lubricator to clean out all deposits by the discharge valve. In frosty weather the lubricator should be always emptied before the engine is put away to obviate the bursting of the reservoir by frost.

To start a sight feed lubricator, all the valves on the lubricator itself being closed and the reservoir having been previously filled with oil, the steam-cock on the boiler should first be opened and then that controlling admission to the lubricator slightly and carefully raised from its seat to permit of the condensed water filling the sight tubes or chambers; when this preliminary requirement is fulfilled, the cock can be further opened to establish a free connection. The oil regulating valves can next be opened and adjusted to the desired flow of oil, the drops being counted as they ascend the sight tube. All the movements should be slowly made, or a violent disturbance of the oil will ensue, causing the sight chambers to be filled with a milky fluid which will prevent proper observation of the supply.

If with all possible care and after several attempts the water still clouds, the best method of procedure is to close the steam-cock on the boiler, empty the lubricator, fill it with water, and allow this to run out, and try again. The oil should never be allowed to become entirely displaced from the reservoir if it can be avoided, as the whole lubricator will then get too hot, and will have to be allowed to stand to cool, be filled up with cold water and emptied before it will work again. When the lubricator is stopped, as when standing in a terminal station for some time, some drivers prefer to allow the steam-cock on the boiler to remain open, and shut the steam regulating valve on the lubricator itself, as condensed water is always collected in the pipes leading to the lubricator; on some classes of lubricator this practice gives good results.

Some patterns of lubricators have a bye-pass cock separating the water in the condensing chamber from that in the oil reservoir, so that in re-charging with oil, by closing this cock the condensed water in the former may be kept there, saving time when the lubricator is re-started. The larger the condensing column the steadier a lubricator is usually found to work, but obviously this entails a longer interval after the steam-cock is opened before it commences operation, as there is more space to be filled with condensed water.

The sight glasses should be examined and replaced from time to time as they get worn, and are then liable to burst in service.

NATIONAL CODE OF ENGINE HEADLIGHTS.

ALL the main lines of British railways have adopted an uniform code of engine headlights to replace the various codes at one time in use, when each company had its own distinctive lights.

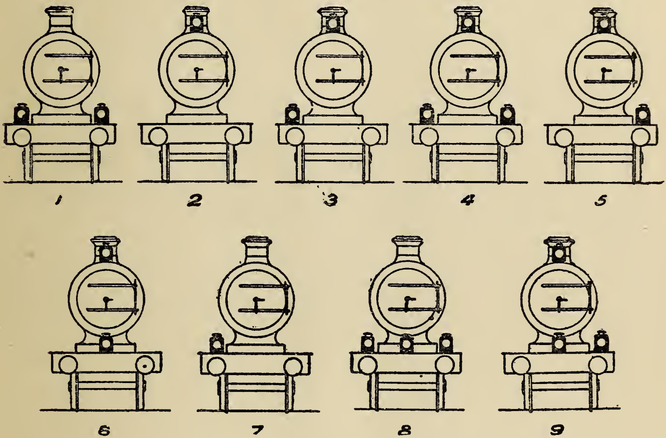


FIG. 14.

A list and diagram of these lights is appended, which will be interesting to many readers. All the lights are white, and except in the case of certain Metropolitan areas the green and blue lights have disappeared. 1. Express passenger trains: Two lights, one over each buffer. 2. Ordinary passenger trains: One light under the chimney. 3. Express fish and fruit trains composed of passenger stock: Two lights, one under the chimney and one over the left hand buffer facing. 4. Empty coach trains: Three lights, one over each buffer and one under the chimney. 5. Fast express goods trains, and fish and meat trains, composed of goods stock: Two lights, one under the chimney and one over right hand buffer. 6. Express cattle, and ordinary express goods trains: Two lights, one under chimney and one at the centre of the buffer beam. 7. Light engines, or engine and brake: One light over left hand buffer. 8. Through goods and mineral trains: Three lights in a horizontal line along the buffer beam. 9. Ordinary stopping goods trains: Three lights, one under the chimney, one in centre of buffer beam and one over right hand buffer.

It will be noticed that special trains, which have hitherto carried distinctive lights, are not provided for: this may cause some confusion. It should be added that the above code of lights is considerably modified for the Metropolitan area.

BOILER DIRT AND SCALE.

WHILST it is generally conceded that a thin "egg shell" coating of scale in a boiler and on the tubes is beneficial, as it protects the metal from corrosion, it is also stated by observers that a deposit $\frac{1}{16}$ of an inch thick will cause an increased consumption of fuel of some 20 per cent, owing to the non-conducting character of the scale. A covering of the heating surface to the extent of half an inch thick would entail an additional consumption of 60 per cent. All water used for feed purposes, if untreated, contains a certain proportion of solid matter in suspension and mineral salts in solution, and although the quantity per gallon may appear insignificant, this totals to a considerable figure in a locomotive boiler after a day's work, as when evaporated into steam the water parts with practically all substances held in solution. If the feed contains but 20 grains of salts, etc., per gallon it means that over 6 lbs. of solid matter will be deposited from every 10 tons of water used. Assuming a mileage of 200 miles per day with an evaporation of 20 tons of water, we find that quite 12 lbs. of deposit will accrue, a by no means insignificant quantity if allowed to remain and accumulate.

The chief ingredients in boiler scale are sulphate of lime and carbonate of lime and magnesia. The lime salts become insoluble in hot water and are precipitated as the water reaches a temperature of 310° F, which equals that of steam at 80 lbs. pressure per sq. in.

Heating the feed water to a temperature approaching that mentioned will, it is obvious, cause the greater proportion to be deposited, as is exemplified in the exhaust portion and receiver of an exhaust injector.

When sulphate of lime is contained in the feed water to an excessive degree, petroleum has been found a satisfactory agent to cause softening of the scale. Refined oil, however, should be alone used, as crude products may affect the plate and tubes. Sight feed apparatus has been introduced to secure a constant delivery of oil to the feed water delivery, but on locomotives it has not been so successful as on stationary boilers owing to the difficulty of securing a steady feed, independent of the jolting, etc., of the engine.

Probably the most practical method of dealing with the whole question is to employ a satisfactory "softening" apparatus, arranged to meet the exact requirements of the water at each particular installation. Considerable attention has been lately devoted to the subject and some large plants have been erected. As a check on our statements as to quantity of solid matter introduced into locomotive boilers in the feed, we may mention that it is stated that 70 tons of deposit are annually collected in the large plant erected by the North London Ry. Co., just outside the Broad Street station.

The non-admittance of all this material into the boilers of the engines frequenting Broad Street must reflect in an economy of fuel.

SANDING THE RAILS.

MANY broken coupling rods, crank pins, and even crank axles owe their failure primarily to the improper and reckless use of sand on the rails. Employed carefully and with judgment, the contents of the sandboxes of a locomotive will often make all the difference between a successful run on time under adverse circumstances and a reported inability to keep the running due to engine slipping, loss of time in starting, etc.

Clean, sharp sand, properly dried and screened, is essential; any containing saline ingredients is not to be recommended, owing to its tendency to absorb moisture and clog in the sand boxes and pipes.

The position chosen for the sandboxes on British locomotives does not recommend itself as the best for securing dry sand, but it possesses many advantages for filling, etc., so long as the handling of the sand is restricted to buckets. The Continental sandbox on the boiler barrel has been tried in this country; it was the practice for many years on the North London Railway, and was adopted on the first "Mogul" engines built for the Great Eastern Railway; only one box was required for one pair of wheels, it is true, but the location necessitated a high lift for the sand and often meant a general sprinkling of the motion during the operation of filling up, as no pneumatic arrangements were provided, and hot bars, gudgeon pins, big ends, etc., resulted. The engines built by American firms for some of the English railways a few years back also have one sandbox on the top of the boiler.

When an engine slips and the application of sand is required the regulator should be closed before the sand valves are opened. If when starting away slipping is continual, the reversing gear should be kept in full gear and the admission of steam controlled by the regulator, whilst a sprinkling of sand is applied in just that proportion necessary to secure the requisite grip. The turning force is more regular with the expansion links in "full gear" than when notched up, as explained in the chapter entitled "Driving a Single."

An excess of sand means additional resistance to the train, and no benefit accrues from a thick coating of grit rolled down on the rail-head by the wheels and often thrown round by the flanges to be eventually caught by the axleboxes to heat the bearings and cut the journals.

Whilst many drivers still prefer the older hand worked valves, the general adoption of steam or air operated devices is a feature of the modern locomotive. These apparatus are certainly more economical in the use of sand, and also place it exactly where it is wanted, between the tread of the wheel and the face of the rail.

In rough windy weather, with the ordinary hand-worked sanding arrangements, but a very small percentage of the sand expended is used to advantage. To remedy the trouble in this direction it is usual to provide a short piece of rubber hose at the end of each sand pipe, which can be adjusted to close quarters with the rails when required.

Careful drivers and firemen should make sure *both* sand valves (on each side of the engine) are working well, and *both* boxes supplied with sand. Sanding one side and not the other is not an uncommon cause of broken coupling rods and crank pins.

For use with the brakes, probably the hand sanding gear gives best results. A plentitude of sand in this case adds to the resistance, and as quick action is required on both sides of the train nothing short of a full delivery through the sand pipes will materially lessen time taken in stopping.

With coupled engines the question of which pair of drivers should be sanded is a vexed one. The adoption of the steam sanders has, however, modified the problem, as by their use it is possible to sand all the coupled wheels at one and the same time, thus avoiding undue strains on the coupling rods and crank pins.

On some railways it is customary to provide the tenders with sandboxes, which is a good practice if a suitable gear is provided to enable both rails to be simultaneously sanded when required for "braking" purposes. This remark especially applies when the trailing drivers of the engine have steam or air apparatus operating for shunting.

Wherever the sandboxes are situated, precaution is to be taken against moisture and damp; the cover should be a good fit and the bushes through which the valve rods work protected by caps or packing, as wet is liable to enter along the spindles by capilliary attraction, and cause the sand to stick just over the valves, and effectually prevent a supply reaching the rails.

DRIVING A "SINGLE."

THE running of a "single" driver locomotive is an art of itself, and a man unaccustomed to the little vagaries of such an engine is almost sure to lose time with the ordinary express train of to-day. The "single" has its likes and dislikes in a marked degree, and will not satisfactorily answer to the rough and ready handling which its coupled contemporary contentedly puts up with.

There are drivers on the express services who, not content with putting their faith in the "single" for long fast runs, will not hesitate to take and keep time with some of the heavier stopping trains, which a "coupled" man would consider a good load.

Slipping when starting is doubtless the chief source of trouble with single driver engines, but this can be avoided to a considerable extent by a judicious handling of the regulator. The start should be made with the regulator only, and no attempt made to "notch" up the expansion gear until the engine is well away with its load. By keeping the valve motion in full gear and admitting steam as required, a steadier and more even turning power is communicated to the cranks, and there is thus less fear of the force applied to the wheels momentarily overcoming their adhesion on the rails. If at the low speed at starting the steam is cut off at 35 or 40 per cent. of the stroke, the propelling power administered by the pistons to the cranks is of a more or less jerky character, and slipping must ensue.

The above remarks also apply to the working of a single engine when negotiating a rising grade, with a somewhat later cut off and the steam supply "wiredrawn" at the regulator, a "single" will do its best on a bank; the sanding should be kept slightly applied over those portions where slipping is most likely to occur, but here again care should be exercised, as unnecessary sand on the rails will add to the resistance of the train. It is as well for the fireman to shut off the feed and to thicken up the fire a little, preparatory to entering a risky section, for in addition to causing priming, slipping invariably pulls a thin fire to pieces, and steam may be lost at a critical point from this if precautions are not taken in time.

On the down grades "let her run" is the motto of the "single" driver, and a good engine will do those parts of the journey with the links practically in "mid-gear." With single slide bars it is advisable to "link up" and keep the steam on to take the weight of the crossheads from the bars when running fast down a favourable bank.

Generally a "single" is more sensitive than a coupled engine, and must be treated accordingly. It will probably burn a few more lbs. of coal on difficult sections, but these can be more than regained with care on favourable stretches.