Form 2500 Standard

INSTRUCTIONS

FOR

ENGINEMEN

GOVERNING

THE CARE, MAINTENANCE AND ECONOMICAL OPERATION OF THE STEAM LOCOMOTIVE

Copyright 1921 by

ATCHISON, TOPEKA AND SANTA FE
RAILWAY COMPANY

Revised 1929
Revised 1942

God was wasting His Time Was He!

№ 619

THIS BOOK IS THE PROPERTY OF
THE SANTA FE RAILWAY SYSTEM,
__________ DIVISION,
AND IS LOANED TO

NAME	OCCUPATION
J L White	

who, by accepting, agrees to return it to the proper officer when called for, or forfeit one dollar.

PREFACE

The instructions contained herein are for the information and guidance of employes of the Atchison, Topeka and Santa Fe Railway Company, whose duties require that they be familiar with the care and operation of the locomotive.

It is the desire of this company to employ firemen who will in time become competent locomotive enginemen, and who by proper study and application to duty may prepare themselves for appointment to higher positions of responsibility. This requires that an employe should have at least a common school education, good habits and be in good physical condition. He should be alert, with good reasoning faculties, and a man of sound judgment. Having these qualifications advancement will come to those who are conscientious in discharging their duties and who devote some of their leisure hours to study.

When entering the service as a locomotive fireman an employe should understand that he is entering his apprenticeship as an engineer, and should, during his period of firing service, avail himself of every opportunity to learn everything possible connected with his duties and with the duties he will be called upon to perform after being promoted. This book is issued for the purpose of assisting such firemen and for the information of enginemen already in the service. All such employes are invited, in fact, urged to go to the Master Mechanic, General Foreman, Road Foreman, Fuel Supervisors and Air Brake Supervisors, or any other official, and ask them for such information as may be required in connection with their work.

It is good practice to observe how other men care for breakdowns or conditions which effect the proper operation or maintenance of the locomotive, thereby benefiting through the experience of others. However, failure to practice what you learn will result in its soon being partially or wholly forgotten. Remember that it is your duty to ascertain, as far as tests and examinations will permit, the general condition of locomotives under your charge, and either to apply the proper remedy or make a clear report of any troubles on the usual work reports.

Much valuable information may be obtained by noting the construction of the various parts of the locomotive while it is undergoing repairs. For this purpose periodical visits to the shop and roundhouse will provide a fund of information difficult to obtain otherwise, as the interior parts are dismantled and may be examined at leisure.

Study carefully the diagram showing the complete locomotive, in order to become familiar with:

The boiler, which is a power generating plant.

The engines for utilizing the power generated.

The frames to provide a foundation for carrying the boiler and engines.

A series of wheels secured in the frames and which are turned by the engines.

INDEX

Name and Index Number of Locomotive Parts Fig. 1.

1. Cab
2. Cab ventilator lever
3. Cab ventilator
4. Whistle lever
5. Whistle rope
6. Steam whistle
7. Water glass
8. Gauge cock
9. Main throttle
10. Throttle quadrant
11. Main throttle stem
12. Main throttle bell crank
13. Main throttle valve
14. Throttle stand pipe
15. Throttle dry pipe
16. Reverse lever
17. Reverse lever quadrant
18. Reverse lever reach rod
19. Power reverse gear
20. Power reverse gear reach rod
21. Reverse shaft arm.
22. Reverse shaft
23. Blow off cock lever
24. Blow off cock
25. Adjustable seat box
26. Adjustable seat cushion
27. Adjustable seat back rest
28. Brakeman's seat
29. Stoker elevator
30. Stoker distributor elbow
31. Automatic stoker engine
32. Fire door ring or opening
33. Fire box
34. Fire box door sheet
35. Crown sheet
36. Back flue sheet
37. Back head
38. Throat sheet
39. Wrapper sheet
40. Staybolt
41. Boiler stayrods
42. Crown sheet radial stays
43. Expansion stays
44. Arch flue plug
45. Arch tube
46. Brick arch
47. Mud ring
48. Grate frame
49. Grate frame support or bracket
50. Rocking grate
51. Dump grate post

52. Grate shaker post
53. Power grate shaker cylinder
54. Power grate shaker reach rod
55. Grate shaker post reach rod
56. Grate connecting rod
57. Grate shaker arm
58. Ash pan
59. Front ash pan slide post
60. Center ash pan slide post
61. Back ash pan slide post
62. Front ash pan hopper
63. Center ash pan hopper
64. Back ash pan hopper
65. Ash pan slide
66. Cylinder cock operating lever
67. Cylinder cock reach rod
68. Cylinder cock lever
69. Cylinder cock slide rod
70. Cylinder cocks
71. Water column
72. Hand rail or grab iron
73. Injector throttle
74. Injector steam pipe
75. Injector
76. Injector feed pipe
77. Injector overflow muffler
78. Injector branch pipe
79. Injector line check
80. Boiler check
81. Electric headlight turbine and generator
82. Superheater flue (superheater boiler flue)
83. Boiler flue
84. Superheater tubes or units
85. Superheater header
86. Front flue sheet
87. Fountain
88. Fountain dry pipe
89. Tate flexible staybolt
90. Tate flexible flush sleeve staybolt
91. Trailer spring equalizer
92. Trailer spring back hanger
93. Trailer spring front hanger
94. Trailer spring
95. Trailer equalizer
96. Trailer truck frame
97. Trailer truck box
98. Trailer truck wheel
99. Trailer truck equalizer post
100. Trailer radius bar
101. Driving box brass
102. Driving box
103. Driving box cellar

104. Driving box wedge
105. Driving box shoe
106. Driving box adjusting spring and rod
107. Driving box cellar bolt
108. Driving spring saddle
109. Driving spring equalizer
110. Driving spring hanger
111. Main driving spring
112. Back driving spring cross equalizer hanger
113. Main frame back section
114. Main frame
115. Main frame front section
116. Pedestal brace or binder
117. Back driving brake hanger
118. No. 3 Driving brake hanger lever
119. No. 2 Driving brake hanger lever
120. Front driving brake hanger lever
121. Driving brake head
122. Driving brake shoe
123. Driving brake adjusting screw
124. Driving axle
125. Driving axle key
126. Driving wheel
127. Driving wheel tire
128. Driving wheel counterbalance
129. Back section or No. 3 side rod
130. Intermediate or No. 2 side rod
131. Front or No. 1 side rod
132. Side rod knuckle joint
133. Main rod
134. Main rod back end
135. Main rod grease cup
136. Back crank pin
137. Intermediate or No. 2 crank pin
138. Front crank pin
139. Main crank pin
140. Running board
141. Running board bracket
142. Front running board
143. Back sand pipe
144. Front sand pipe
145. Pneumatic sand traps
146. Sand box or dome
147. Sand box cover
148. Main reservoir
149. Main reservoir flexible pipe union
150. Main reservoir radiating or equalizing pipe
151. Safety valves
152. Blow off valves
153. Steam dome
154. Hand rail
155. Boiler lagging
156. Boiler jacket

157. Boiler waist sheet
158. Engine number indicator
159. Bell
160. Pneumatic bell ringer
161. Smoke stack
162. Stack extension
163. Spark arrester slide
164. Spark arrester
165. Exhaust pipe joint cover plate
166. Spark arrester baffle
167. Front end door deflector
168. Handhole for cleaning and inspecting inside smoke box
169. Washout plug to remove cinders
170. Front end or smoke box
171. Front end door ring
172. Front end door
173. Front end number plate
174. Headlight
175. Smoke arch or pilot brace
176. Pilot beam
177. Pilot heel brace
178. Pilot step
179. Pilot
180. Pilot automatic coupler
181. Automatic coupler lock lifter
182. Automatic coupler uncoupling lever
183. Automatic coupler lock lifter chain
184. Engine truck center casting
185. Engine truck spring hanger
186. Engine truck spring
187. Engine truck long equalizer
188. Engine truck long equalizer post or fulcrum under cylinder saddles
189. Engine truck radius bar
190. Engine truck axle
191. Engine truck wheel
192. Cylinder saddle
193. Cylinder
194. Front cylinder head
195. Back cylinder head
196. Main valve chamber
197. Main valve bushing
198. Main valve packing rings
199. Main or piston valve
200. Front main valve chamber head
201. Main or piston valve stem
202. Valve stem cross head guide
203. Valve stem cross head
204. Steam pipe connecting superheater header to outside steam pipe connection
205. Outside steam pipe connection
206. Exhaust pipe
207. Blower pipe

208. Front steam port to cylinder
209. Back steam port to cylinder
210. Steam piston head
211. Steam piston head bull ring
212. Steam piston cylinder packing rings
213. Piston rod
214. Cross head or piston rod key
215. Cross head wrist pin
216. Cross head
217. Valve gear union link
218. Combination lever
219. Radius bar
220. Radius bar hanger
221. Valve gear frame or link bearer
222. Reversing link
223. Valve gear eccentric rod
224. Valve gear eccentric crank
225. Bottom guide bar
226. Top guide bar
227. Guide step
228. Guide yoke or bearer
229. Counterbalance spring
232. Feedwater heater
233. Feedwater heater bracket
234. Steam pipe for feedwater heater

Tender

237. "T" brace
238. Ladder ring
239. Ladder
240. Back wall of tank
241. Hand rail
242. Hand rail column
243. Uncoupling rod arm
244. Tender end sill
245. Uncoupling rod
246. Coupler pin lifter chain
247. Coupler knuckle
248. Coupler or draw bar
249. Draw bar carrier
250. Tender step
251. Brake rod adjusting screw
252. Draw bar yoke
253. Brake adjusting rod
254. Draft gear crosstie
255. Draft gear
256. Journal box spring seat
257. Journal box wedge
258. Journal box brass
259. Truck pedestal
260. Truck pedestal shoe
261. Wheel flange
262. Journal

263. Journal box packing and oil cellar
264. Pedestal tie
265. Brake lever
266. Brake rod
267. Brake lever and brake beam connectors
268. Brake beam
269. Swing hanger
270. Truck frame center member
271. Truck center casting liner
272. Truck bolster
273. Truck center casting pin
274. Truck center casting
275. Brake rod supports
276. Chafing plates
277. Center pin key
278. Side bearing
279. Tender body center casting
280. Brake lever equalizer carrier
281. Brake lever equalizer
282. Truck frame end member
283. Cylinder dead lever
284. Tender frame
285. Brake cylinder
286. Brake rod adjuster
287. Tool box hasp
288. Tool box
289. Brake piston rod jaw
290. Cylinder floating lever
291. Tender frame floor
292. Tank bottom
293. Locomotive number
294. Tool box hinge
295. Floating lever carrier
296. Safety chain anchor
297. Truck spring
298. Truck spring hanger
299. Truck equalizer
300. Truck equalizer fulcrum pins
301. Brake shoe key
302. Journal box water cooling valve
303. Brake hanger lever pin
304. Truck safety chain
305. Brake hanger lever
306. Truck wheel
307. Journal box lid spring
308. Journal box lid
309. Journal box
310. Truck frame
311. Brake head pin
312. Brake head adjusting screw
313. Brake beam journal
314. Brake head
315. Brake shoe

316. Pedestal tie bolt
317. Re-enforcing bead of truck frame
318. Main draw bar pin
319. Main draw bar pin support
320. Main draw bar pin keeper
321. Safety draw bar pin keeper support
322. Safety draw bar pin keeper
323. Safety draw bar pin
324. Safety draw bar pocket
325. Main draw bar
326. Tank hose
327. Safety draw bar
328. Tank hose clamp
329. Tank hose nut
330. Tank hose strainer
331. Tank hose strainer support
332. Floating chafing plate
333. Engine chafing plate
334. Tender chafing plate
335. Chafing plate wedge
336. Main draw bar pocket
337. Draw bar pin bushing
338. Tank goose neck
339. Tank strainer
340. Stoker conveyor shaft
341. Stoker conveyor shaft knuckle joint
342. Stoker conveyor trough
343. Stoker conveyor screw
344. Stoker conveyor bearing
345. Back wall of conveyor opening in tank
346. Run way for conveyor supporting wheels
347. Tank water leg
348. Tank coal space floor
349. Bend in coal space sheet
350. Stoker slide plates
351. Stoker conveyor crusher
352. Stoker conveyor ball joint
353. Apron hinge
354. Apron
355. Tender deck
356. Coal guards
357. Tank step
358. Water keg drain cock
359. Water keg
360. Ice
361. Water jug
362. Tank valve stem nut
363. Tank hand hold
364. Tank valve stem
365. Tank valve stem lock wheel
366. Tank valve stem handle
367. Coal gate ell.
368. Coal gate

369. Coal guard around tool box
370. Tool box
371. Tank collar extension
372. Coal space slope sheet
373. Coal space slope sheet supporting "T"
374. Coal space slope sheet extension plate
375. Coal space back wall
376. Coal space back wall support
377. Marker lamp box
378. Tank top sheet
379. Tank collar
380. Splash plates
381. Cross brace for tank side walls
382. Tank drain pipe
383. Hinge for man hole cover
384. Man hole cover
385. Man hole collar
386. Man hole cover handle
387. Man hole cover latch
388. Bead around tank collar
389. Air vent in man hole collar

THE LOCOMOTIVE BOILER

Construction and Name of Parts

Fig. 2 shows the construction and name of parts of a modern radial stay extended wagon top type of locomotive boiler, which consists of an oblong box with a circular top made of steel plating, connected to a cylindrical part which is commonly known as the barrel of the boiler. That part of the boiler enclosing the firebox is known as the outer casing or shell. The firebox corresponds in shape to the back end and sides of the outer casing or shell, a space being provided between the firebox sheets and those of the outer casing which provides for the firebox being surrounded by water. The front, or cylindrical part of the boiler encloses the flues which are secured at the front to the front flue sheet and at the back to the inner or firebox flue sheet.

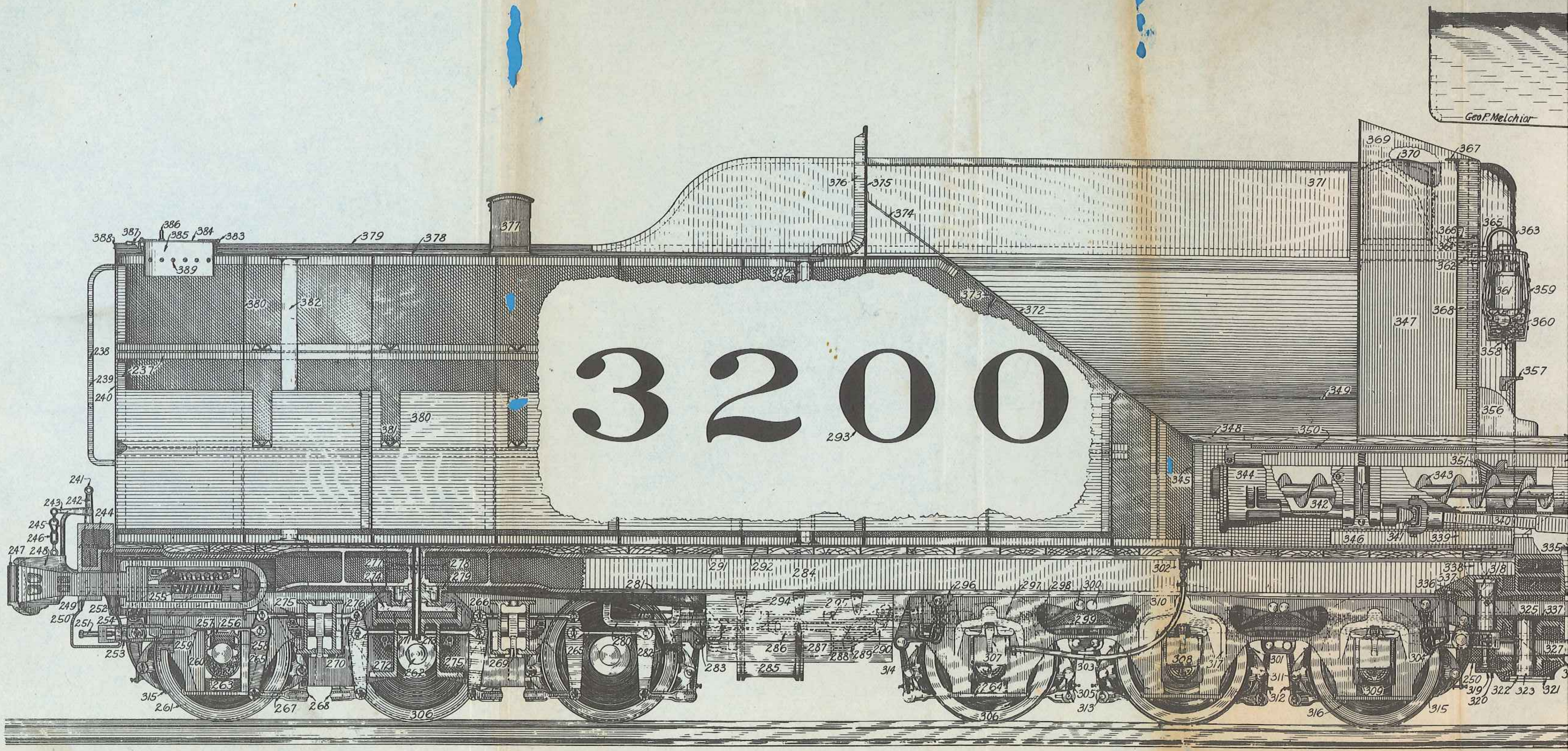
This arrangement provides that all parts of the firebox, as well as the flues, are completely surrounded by water, and it also provides that when fuel is burned in the firebox, the heat will be transmitted by the flues and firebox plates to the water; the unused gases and smoke having free passage from the firebox through the flues to the smoke box and smoke stack.

The smoke box is formed by extending the cylindrical part of the boiler beyond the front flue sheet. The boiler shell is provided with a steam dome on top of the shell which forms a chamber where steam may collect and free itself from the water in the boiler before passing through the throttle valve to the cylinders.

The flues in a locomotive boiler are known as fire tubes, because the heat passes through them, while the arch tubes, of which there are usually four in each firebox, are called water tubes because the fire is on the outside and the water passes through them.

The firebox sheets and flues constitute what is known as the heating surface. In addition to this heating surface there is additional, or superheater heating surface in many boilers, which superheats the steam after it leaves the boiler and while it is passing from the boiler to the cylinders. Comparing the flue heating area with that of the area of the firebox plates shows that the plate heating surface equals only five per cent of the flue heating surface, but the five per cent of firebox heating surface generates about forty per cent of the steam. This fact should be remembered.

In the locomotive boiler a large number of small flues are provided instead of a few large flues, in order that the heat and gases passing from the firebox to the smoke box will be split up and come into contact with a larger flue surface. If large flues were used great quantities of heat would pass through the center of the flues without coming into contact with the surface of the flue, such heat would pass away and be lost. A large number of small tubes also provides for the heat being more evenly distributed through the boiler shell water space. The small flue can be made of thinner material, which permits the heat to be


Geo P. Melchior
3200

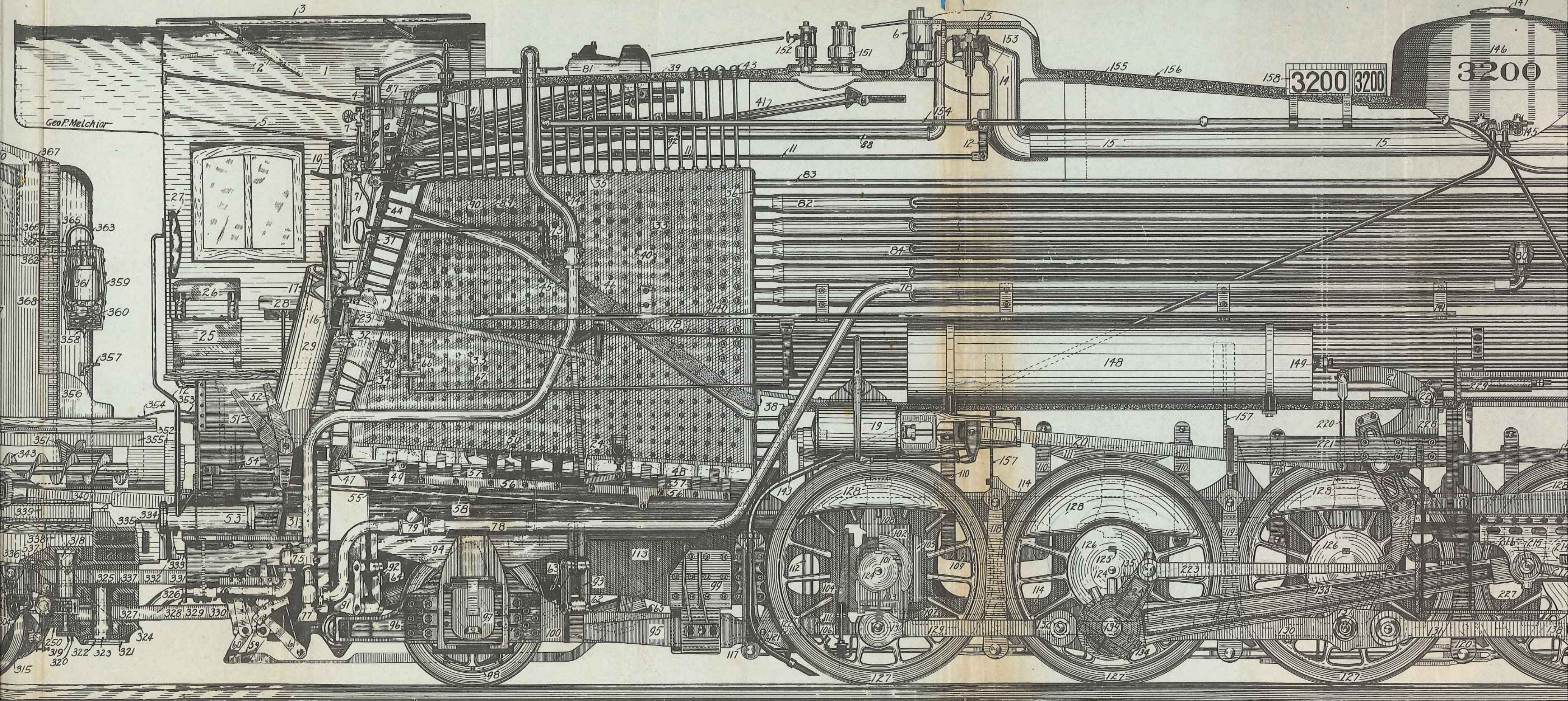
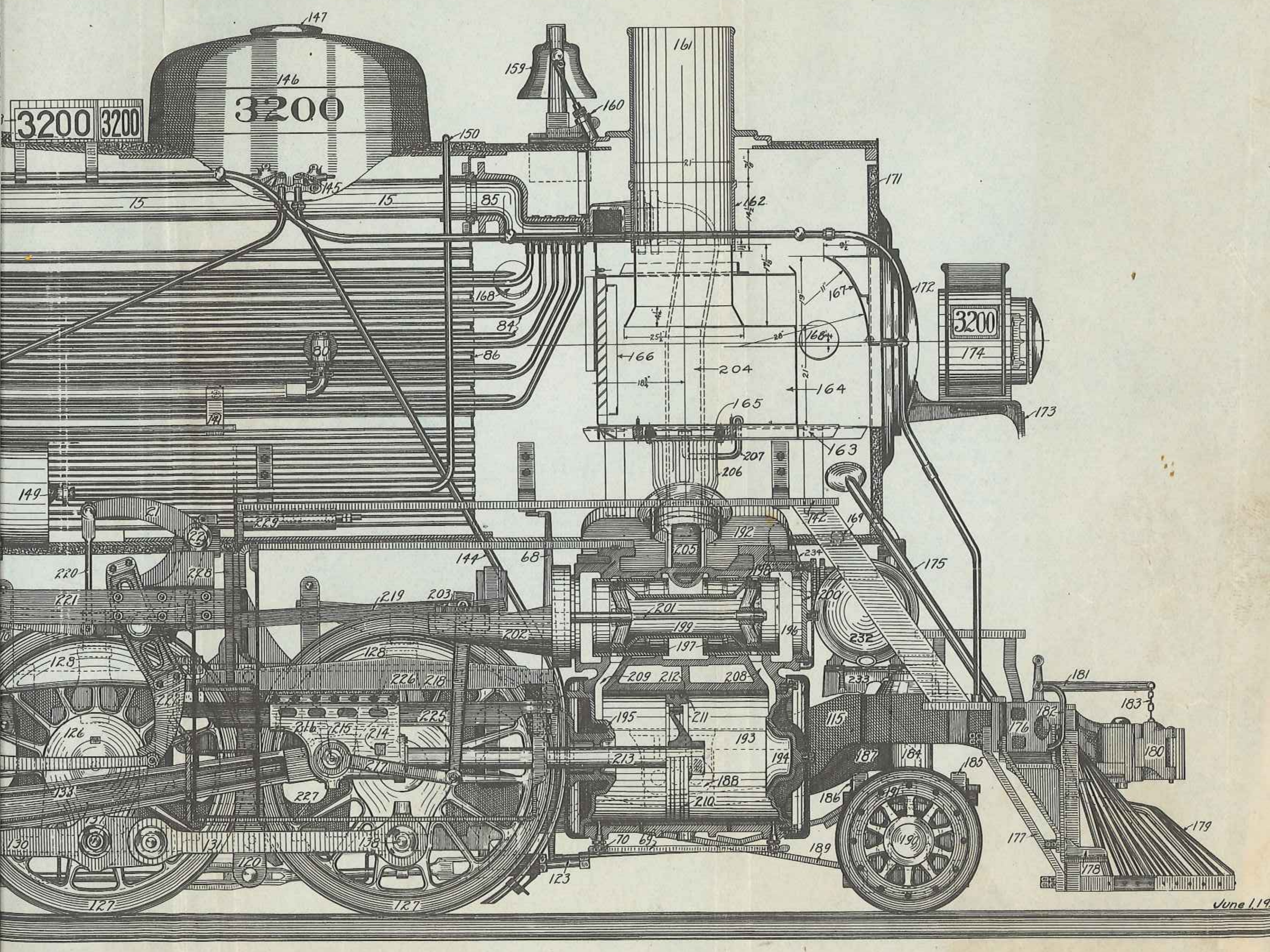


Fig. 1.


147
146
3200
3200
3200
159
160
161
150
171
15
15
145
85
162
172
168
167
84
168
174
3200
80
86
166
204
164
165
173
163
207
206
149
21
229
142
169
192
22
234
220
228
144
68
205
175
221
219
203
198
201
200
202
199
196
232
128
197
129
226
218
209
212
208
233
181
183
225
195
211
115
176
182
126
216
215
214
193
180
217
213
194
187
184
185
188
133
227
210
186
191
179
130
131
138
70
69
189
190
177
120
178
123
127
127
June 1, 19

more easily transmitted to the water which surround the flues.

In the extended wagon top type of locomotive boiler the back part or outer shell is considerably larger in diameter than the front section or cylindrical part; while the straight type of boiler has the outer shell and cylindrical part of practically the same diameter. The extended wagon top type therefore allows more steam and water space and gives superior performance in foaming water territory.

Locomotive boilers are made entirely of steel, except staybolts and stays, which are of iron. The crown sheet is supported by what are called radial stays reaching from the crown sheet to the exterior wrapper sheet.

There are three common designs of fireboxes in general use. The narrow deep firebox, which is between the frames and extends below the top frame rails. The semi-wide shallow firebox which rests on top of the frames and extends to the outside edges of the frame rails, and the wide firebox type having a firebox wider than the frames and extending outside the frame rails on both sides, and resting on top of the frame rails, or expansion brackets which are secured to the top of the frames.

The combustion chamber for large locomotives was originally introduced for the purpose that its name implies, of providing increased firebox area for combustion purposes. As locomotives grew larger and the wheel base longer, it then became a question of limiting the length of flues. It was found that when flues were more than 21 or 22 feet long, there was considerable more trouble in respect to leakage and in order to keep the flues within those limits of length it was necessary to lengthen out the firebox which was done by extending the flue area into the boiler.

Combustion chambers have been provided on locomotives of the 3700, 3751, 3765, 3776, 3800, 5000 and 5001 classes, the length of combustion chambers varying from 42 inches to 64 inches on these classes. In addition a few installations have been made on the 3400, 3450, and 4101 classes.

There is also an advantage of the combustion chamber, in addition to allowing for shorter flues, the heating surface of the firebox sheets composing the combustion chamber is vastly more efficient than the increased length of flues would be if the combustion chamber was not used.

The combustion chamber also serves to protect the ends of the tubes from cold air which comes up through the grates at the front end of the firebox, in addition to providing a long flameway for the burning gases, which is particularly desirable with oil, or coal, having a large percentage of volatile matter.

Effect of Heating, Cooling and Low Water

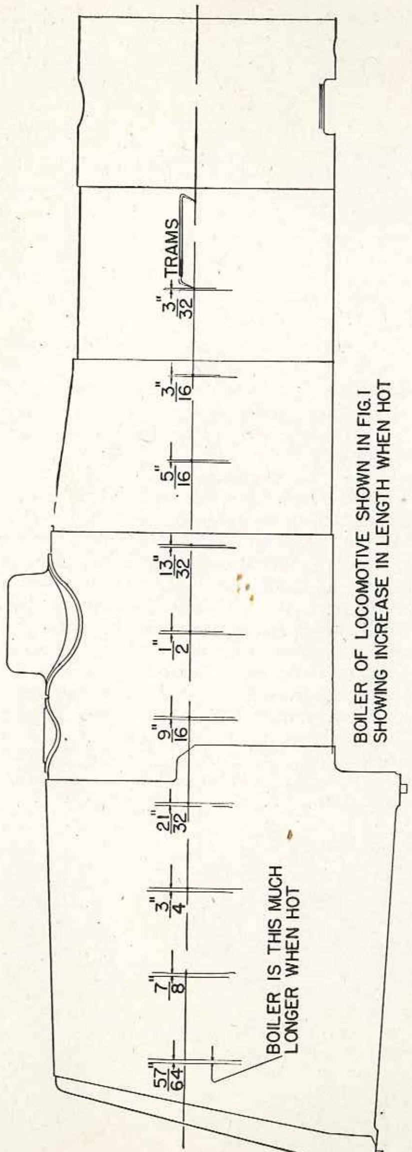
When the crown sheet or firebox sheets are not covered with water, they become overheated very quickly with a hot fire in the firebox. If for any reason water is not maintained over the crown sheet, and the sheet becomes overheated, the fire must be put out or deadened at once. and under no circumstances

should cold water be forced into the boiler. The boiler should be cooled down before any attempt is made to refill it, because forcing cold water into the boiler when it is very hot produces sudden changes in the temperatures of the various parts of the sheets, and sets up destructive strains.

The prevention of destructive strains and stresses, or reducing their amplitude should interest all who have to do with the upkeep of the locomotive. In order to bring out clearly and simply the cause of destructive stresses it should fully be understood that the contraction or expansion in a body of metal when changes of temperature occur is irresistible. A firebox sheet expanding or contracting as a result of a change in temperature cannot be restrained. It is certain to find relief in some direction, either by self destruction or destroying the obstacle opposing its movement.

The life of a locomotive boiler or firebox is dependent largely upon the care which it receives while in service. It is not possible in the operation of a locomotive to avoid all strains and stresses, but it is possible, practical and beneficial to reduce the frequency of the stresses and also their amplitude. In other words, if by any means the severity of strains is reduced even though their frequency be increased, the period between failures will be prolonged, the time between repairs and the life of fireboxes and boilers will be lengthened.

Fig. 3, which is a diagram of the boiler shown in Fig. 1, illustrates the action of metal when heating and cooling takes place. It will be noted that the boiler is divided into sections. After steam is generated in the boiler to 200 lbs. it is found that the boiler has expanded nearly one inch, which demonstrates that metal expands as heating takes place and that when the boiler cools the metal contracts. Expansion and contraction of the metals thus sets up strains and stresses at various parts in the boiler, and it is important that as these strains are developed that they be developed slowly, in order that the effect of heating or cooling will be distributed throughout the boiler so that the expansion or contraction will be as uniform as possible throughout all its parts.



BOILER OF LOCOMOTIVE SHOWN IN FIG.1 SHOWING INCREASE IN LENGTH WHEN HOT

Fig. 3.

TEMPERATURES OF STEAM AND WATER

Working injector or water pump while locomotive is standing causes more frequent and greater inequality of temperatures throughout the boiler and the development of more destructive stresses than any other cause. To illustrate: Temperature of the steam in a locomotive boiler at 190 pounds pressure is 383 degrees Fahrenheit. This is also the temperature of the water at that steam pressure. When an injector is operated the water passing through the injector on its way to the boiler is heated to a temperature of from 160 to 200 degrees. It is therefore from 183 to 223 degrees cooler than the water within the boiler. The water from the injector being cooler is heavier than the higher temperature water in the boiler, and on entering the boiler must take a downward course and continue downward until it reaches the lowest part. The weight of a cubic foot of water as it enters the boiler from the injector is 60⅛ pounds, while a cubic foot of water at 190 pounds steam pressure, or 383 degrees, is only 54¼ pounds. A cubic foot of water at 383 degrees is 5⅞ pounds, or 9 per cent lighter than the water at 200 degrees delivered into the boiler from the injector. This difference of weight makes it clear why the cooler and heavier water seeks the lower levels and displaces the hotter lighter water.

Table Showing Temperatures of Steam at Different Pressures

Boiling point	212°
100 lbs.	337.8°
160 lbs.	370.6°
180 lbs.	379.5°
200 lbs.	387.8°
220 lbs.	395.6°
250 lbs.	406°
300 lbs.	421.7°

CAPACITY OF WATER SPACES AND EFFECT OF OPERATING WATER PUMP AND INJECTOR WITH LOCOMOTIVE STANDING.

That part of the boiler immediately above the mud ring and extending upward toward the crown sheet, is known as the water leg of a boiler. Referring to Fig. 4 (which is a reproduction of the firebox end of the boiler shown in Fig. 1) it will be noted that when the water is raised 28 inches above the mud ring that the water leg and the bottom of the boiler is filled up to the third row of flues. This space when filled with water contains 396 gallons. Any inch of the boiler water space that the lower half of the water glass shows will average 84 gallons, therefore, when the injector delivers enough water to the boiler to show an increase of one inch in the glass, from 19 to 20 inches of cooler water flows to the lower firebox water spaces, and reduces the temperature of the parts of the firebox sheets it is in contact with. These figures show that if water is injected into the boiler until the glass shows a gain of five inches, the height of the cooler water in the lower parts is from 28 to 29 inches, which not only covers 28 inches of firebox sheets, but three rows of the lower flues are submerged in water from 100 to 200 degrees cooler than the water above. If the flues are twenty feet long, the cooler ones are from ⅛ to ¼ of an inch shorter than the upper ones, and the side sheets are from $\frac{1}{16}$ to ⅛ inch shorter at the cooler portions than at the hotter parts above; and these variations in length between parts of the same sheet and between the upper and lower flues establish the stresses that develop leaks and the necessity for repairs. The cooler water assumes a horizontal strata under the hotter water, as shown below the 28 inch line in Fig. 4. The parts affected must conform in length to the temperature of the water they are in contact with. Unequal temperatures between parts of the same structure are the cause of boiler and firebox deterioration. Improper handling of the injector is responsible for more boiler leaks than all other causes combined. A large per cent of these troubles could be avoided by improved handling.

DIAGRAM OF 3160 CLASS BOILER SHOWING WATER CAPACITY IN GALLONS

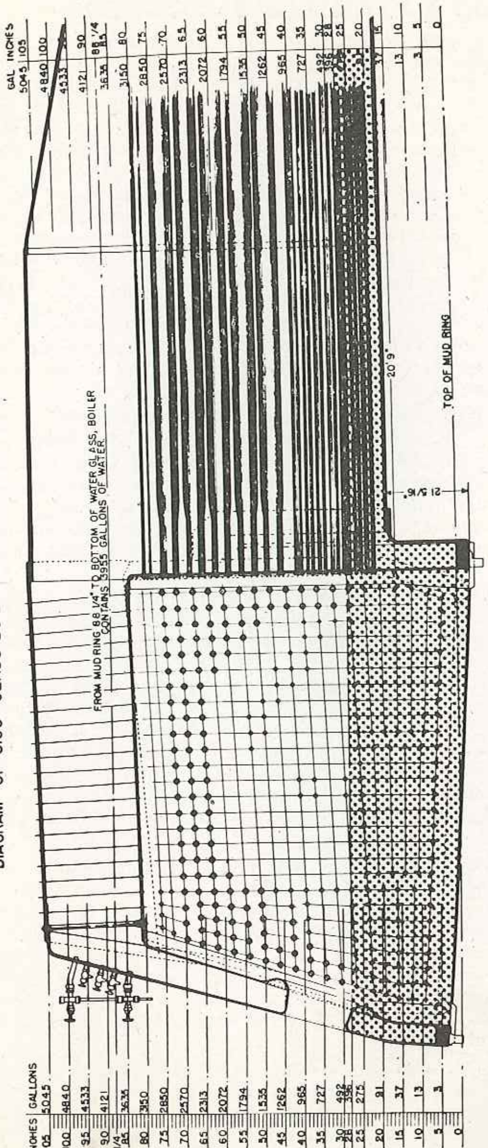


Fig. 4

NOTE: Operating the injector at a rate of 60 to 70 gallons of water per minute will supply about 275 gallons in four minutes and if water is showing at the bottom of water glass, or at 88¼" line, will raise it 3" in water glass; but note as the cold water will settle to the bottom of the boiler to the height of the 25" line, it puts the two rows of flues, from the bottom, as well as lower part of fire-box and boiler under a heavy contractile strain due to the lowering of temperature. These conditions cannot be avoided if the injector is operated when the engine is standing. When the locomotive is not working steam, the injector should be operated for short periods and the water should not be raised over 1" in the glass, at each period. The injector should then be shut off for a few minutes if conditions permit.

SUPERHEATER LOCOMOTIVES

The fire tube or high degree type of superheater is a superheater having tubes which connect at one end to a passage communicating directly with the steam admission or dry pipe leading from the throttle valve. These pipes then extend into large boiler flues, the ends of the superheater pipes reaching back through these flues close to the back flue sheet, where the pipe bends and returns through the flue to the smoke box, another return bend being placed at this point, the pipe again entering the same flue and reaching almost to the first return bend, where another return bend is placed and the pipe extended out into the smoke box and connected to the same casting which contains the live steam passage; however the latter end of this pipe connects to a passage leading to the steam pipes and steam chests. The casting to which these tubes are connected is called the superheater header. One side of the header connects directly to the dry pipe and the other side connects to the steam pipes leading to the valve chambers.

A number of large flues are placed in the top part of the boiler, into each of these is inserted one of the above described coils of pipe. Each one of these coils is designated as a unit, the superheater is therefore made up of a number of units, all connected to one header. Steam, after leaving the throttle valve, passes to the superheater header, then through the superheater tubes or units, back into the header and thence to the valve chambers.

Superheating steam increases its elasticity. However, adding heat to steam does not increase its power to start a load. Two hundred pounds pressure per square inch exerts the same starting force, whether of superheated or saturated steam. A certain pressure of saturated steam represents a certain steam temperature and when saturated steam from a boiler enters a cylinder at 368 degrees, it represents a pressure or force of 170 pounds per square inch, and as it loses its heat it loses its power. Thus when it has lost 100 degrees of heat, that is, when its temperature has been reduced from 368 degrees, to 268 degrees, the steam pressure has also been reduced, falling from 170 pounds per square inch to 40 pounds.

Superheating adds to the steam after it leaves the boiler and before it enters the cylinder, from 100 to 300 degrees of heat. This extra or additional heat is sufficient to overcome the cooling effects of the valve chambers and cylinders to the extent that a higher average pressure is maintained in the cylinders the whole length of the stroke. The maintaining of the steam at a higher temperature in the cylinder is the reason why superheated steam holds its power of doing work longer, and why it does more work than an equal weight of saturated steam.

Ability to obtain or failure to obtain the best results from a superheater rests largely in the hands of the engineman. A simple rule for obtaining the best results may be expressed in seven words: "Keep the water out of the superheater." The

moment the water gets into it, the efficiency of the locomotive drops. Water may not show at the stack or cylinders, the superheater may be turning it into steam, which however is not superheated to the same degree as would be the case if no water were present, and moreover the solids left behind by the water tend to scale up the inside of the superheater tubes, reducing their efficiency. The solid matter also mingles with the lubricants in the cylinders, reducing the lubricating qualities of the cylinder oil.

Fig. 5 shows the fire tube superheater as applied to a locomotive; it consists essentially of the superheater header and a series of superheater units, generally arranged in several horizontal rows across the top part of the boiler.

The superheater header replaces the ordinary tee or "nigger head." It is provided, like the tee, with connections for the dry pipe and steam pipes, but has in addition, internal walls, which prevent the direct flow of steam from the dry pipe to the steam pipes. The connecting passage between the dry pipe and the steam pipes is provided by the superheater units. This compels all of the steam to pass through the superheater units on the way to the cylinders.

Each unit consists of a continuous pipe, formed of four seamless steel tubes, connected by three return bends. The front ends of the units are bent and clamped to conical seats in the face of the superheater header in the smoke box, as shown in Fig. 5. The connections are made steam-tight by ball joints, the balls being formed on the ends of the pipe. The units are placed in the superheater flues which are 5⅜ inches or 5½ inches outside diameter (depending upon whether used with the 2 inch or 2¼ inch boiler tube). They extend full size from the front flue sheet to within about 8 inches of the firebox. Beyond this point the flue is reduced to 4½ inches outside diameter by swaging.

In operation, part of the hot firebox gases flow through the large flues. A proportion of their heat is absorbed by the pipes of the superheater units and transferred to the steam passing through them on its way from the dry pipe to the cylinders. As a result the steam has a higher temperature on reaching the cylinders than when it left the boiler; briefly stated, it is superheated steam.

The above described superheater is known as the type "A."

The type "E" superheater, while being of the general design of the type "A," is constructed so that each unit occupies four boiler flues instead of one as is the case with the type "A."

The large superheater boiler flues used with the type "A" superheaters are 5½ inches in diameter while those used with the type "E" are 3½ inches.

With the type "E" the steam enters the superheater unit pipe from the header but the unit pipe divides in the form of Y before entering the flues, and after being so divided enters two of the boiler flues. Near the back end of the boiler flues return bends are made and the unit tubes return to the front end where

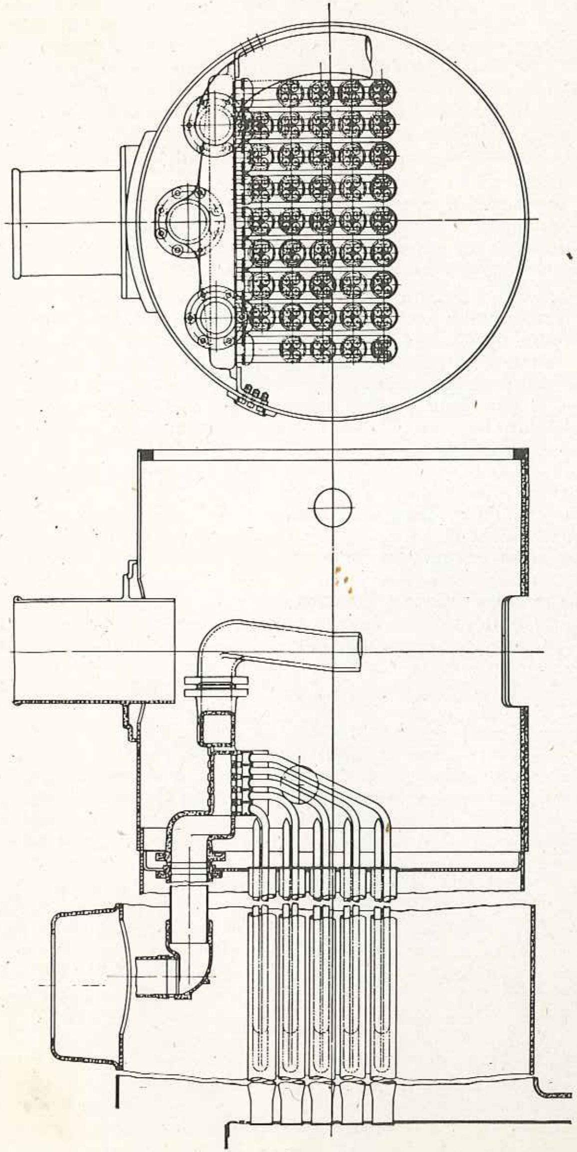


FIG. 5.
Type A. Superheater Arrangement.

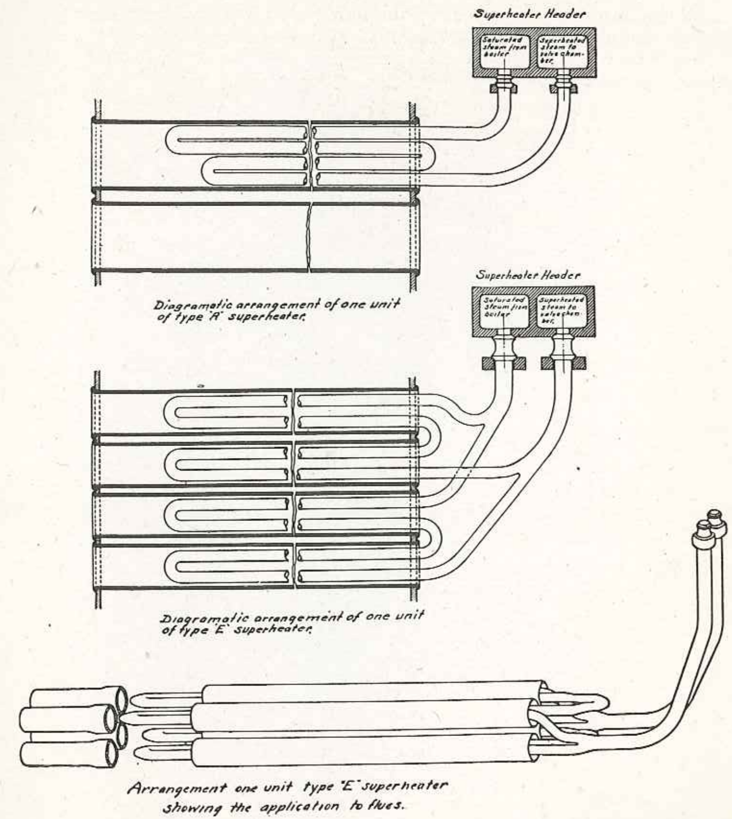


FIG. 6.

large return bends are provided and the two tubes, which comprise the divided unit, re-enter two other boiler flues. After entering the second pair of boiler flues they go to the back end and return in a similar manner, but after again reaching the front end, the two tubes, comprising the unit are again joined by a Y connection and return to the header as a single pipe.

Diagrammatic sketches are shown in Fig. 6 to illustrate piping arrangement of both types of superheaters.

Fig. 7 shows actual construction of the type "E" units and their installation.

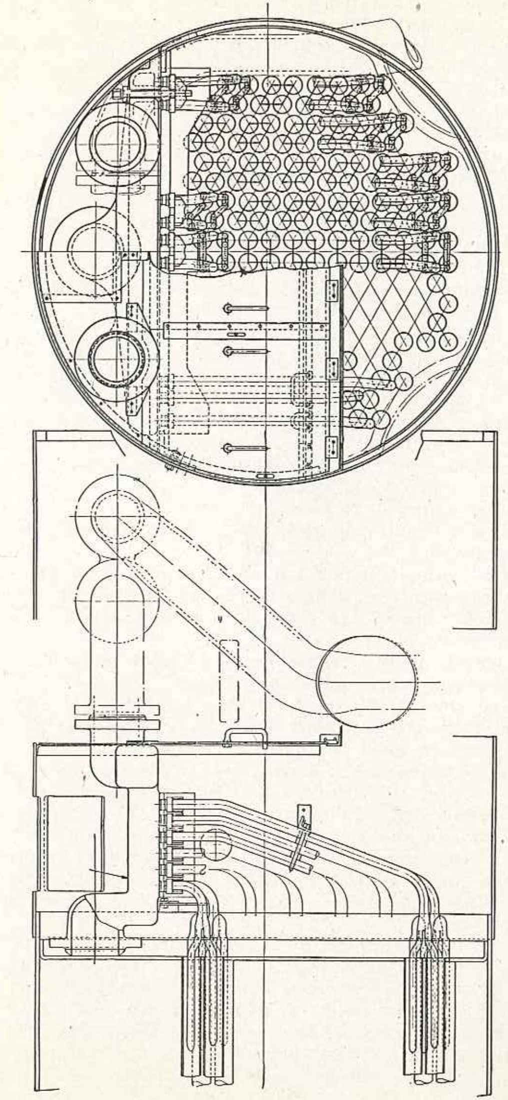


FIG. 7. Type E Superheater Arrangement.

Hand Holes

Hand holes 8 inches in diameter are provided in each side of the smoke box, slightly below the center of the face of the header and directly opposite each other. These hand holes afford a means of inspection to determine whether the superheater unit joints are leaking.

Operation

The general operation of the superheater locomotive is the same as that of the saturated steam locomotive.

Cylinder cocks should be left open to drain the cylinders, etc., while standing. In starting the cylinder cocks should remain open until dry steam appears and the reverse lever should be placed in full gear to insure full port opening to the cylinders and maximum starting power for the locomotive and lubrication the full length of the valve chambers.

When water is carried over into the superheater, closing the throttle does not stop the supply of steam into the cylinders until the water in the superheater has been evaporated and used. This condition of water in the superheater causes trouble in spotting locomotives at water tanks, coal chutes, etc., in switching service and is especially bad in "hump yard" service on account of the lost time in "cuts." Ordinarily it is a sure sign of careless operation.

Water should be carried at the same level on a superheater locomotive as on a saturated locomotive, so that the superheater will receive dry steam.

High water will cause lubrication and packing troubles, lack of power, and slow running. It also increases the fuel and water consumption, which reduces the economies that are available by the use of superheated steam.

Locomotives which do not steam freely should have flues examined to see that they are open and clean.

If the flues are open and clean, test the superheater and the steam pipes for leaks, the locomotive for blows and see that the draft appliances are in good condition.

Leaks of the superheater, steam and exhaust pipes, flues stopped up or leaking all interfere with the steaming of the locomotive and reduce the superheat. Blows in the cylinder and valve packing remove the oil from the wearing surfaces and cause excessive wear of parts, waste of steam and loss of power. When any of the above conditions exist, locate the one that is defective and if unable to make repairs on the line, report same on arrival at terminal.

If abnormal consumption of fuel and water still continues and the above conditions do not exist, go after the "Operation" and see that the superheater is used to superheat steam and not as an auxiliary to the boiler for evaporating the water.

In drifting, sufficient steam should be used to insure the satisfactory distribution of lubricating oil and prevent the suction of dirt and gases from the smokebox into the valve chambers and cylinders.

The lubrication of the cylinders should be constant and regular while the locomotive is working. Remember that it takes 7 or 8 minutes to get oil to the valve chambers after starting the hydrostatic lubricator when it has just been refilled. At other times the lubricator starts to feed promptly after setting the feeds. The lubricator should therefore be started in ample time to insure it feeding oil to valves and cylinders before starting to work steam.

Usually conditions of the valve stems and piston rods give a fair indication of the condition of the inside of the cylinder, i. e., a well lubricated piston rod means a well lubricated cylinder, while the reverse is also true.

The same amount of oil should be fed to the valves of a superheater locomotive as is fed to a saturated locomotive. When locomotives are equipped with oil pipes leading directly to the cylinders, feed the same amount of oil to the cylinders as is fed to the valves.

The temperature of the steam leaving the superheater when the gauge registers 200 pounds boiler pressure, depends upon the efficiency of the superheater, the quality of steam delivered to the superheater and the temperature of the gases in the firebox, flues and superheater flues.

Assuming that the boiler flues are clean and that the water in the boiler is ordinarily clean and the temperature of the fire in the firebox is maintained at its maximum, the maximum degree of superheat can be obtained, and consequently the temperature of the steam leaving the superheater at this time will be at its maximum. The temperature of the steam leaving the superheater with 200 pounds pressure on the boiler, should be from 200 degrees to 250 degrees higher than that of the saturated steam in the boiler. For example, if a locomotive carries 200 pounds boiler pressure, the average temperature of the steam leaving the superheater should be about 600 degrees.

If, however, the firebox temperature is allowed to fall considerably below its maximum, due to firing the locomotive too heavy, or due to a very dirty fire or the admission of too much air through the fire or fire door; or if the flues containing the superheater units become stopped up, or if the water is carried so high in the boiler that a considerable quantity is carried over into the superheater with the steam, or if the water in the boiler becomes foul causing foaming which carries wet steam into the superheater, or if the draft plates are disarranged so that the heat from the firebox is not properly distributed; the temperature of the steam in the superheater will be considerably reduced below that obtained if none of these bad conditions exist.

The presence, therefore, of any of the above conditions which affect the performance of the superheater will cause its efficiency to be lowered in proportion as these faults exist.

Do not expect too much of the superheater. If quantities of water are passed through the superheater with steam, the units get very badly limed up inside. This not only restricts the flow of steam through the pipes but reduces their heating value. Do not carry the water in the boiler too high just because it is not heard or seen at the smoke stack. The superheater is intended to heat steam and not to boil water. The locomotive may be steaming well and still the full benefit may not be obtained from the superheater, as the locomotive may not require the full capacity of the boiler. Do not work a very light throttle and long cut-off under these conditions.

The throttle on a superheater locomotive not equipped with Wagner By-valve should not be closed entirely when making stops until the speed is quite low. The cylinder lubrication will be maintained much better if sufficient steam is used to prevent gases being drawn in through the nozzle or air being drawn in through the cylinder cocks. The throttle opening should be such that it will not provide an undesired power in the cylinders, but at the same time a sufficient amount will be admitted to properly follow the piston and as the speed reduces the amount of throttle opening should be reduced in proportion. The reverse lever should be dropped several notches or approximately half stroke so that steam will be admitted during a greater portion of stroke. Continue to use steam until the speed has been reduced to about 6 or 7 miles per hour in making stops.

THE AMERICAN MULTIPLE THROTTLE

Description

The throttle chambers and the superheater header are combined in one casting and occupy the usual header location in the locomotive front end. The throttle chambers, illustrated in Fig. 8, consist of three compartments, "X," "Y" and "Z." Compartment "X" is in direct connection with the superheated portion of the header and is always under full boiler pressure. Compartment "Y" is in direct connection with the main steam pipe. Compartment "Z" is a balancing chamber and is under boiler pressure when pilot valve is open.

The throttle parts consist of: A pilot valve "2" and main throttle valves "A," "B," "C," "D" and "E," with balancing pistons attached. Cam shaft "3" with bearing "8," "9" and "10." Stuffing box and glands "11" and "14." Valve covers "6" and "7." And the necessary connections between the cam shaft and the cab lever located on the outside of the boiler.

Operation

When the throttle lever in the cab is moved from the closed to the open position, the rotating motion imparted to the cam shaft, first opens pilot valve '2," admitting steam at boiler pressure to compartment "Z" (or balancing chamber). Further movement of the throttle lever opens the main valves one after the other until all of the valves are open. Steam then flows from the superheated compartment of the header and throttle compartment "X" into compartment "Y" and thence into the main steam pipes of the locomotive.

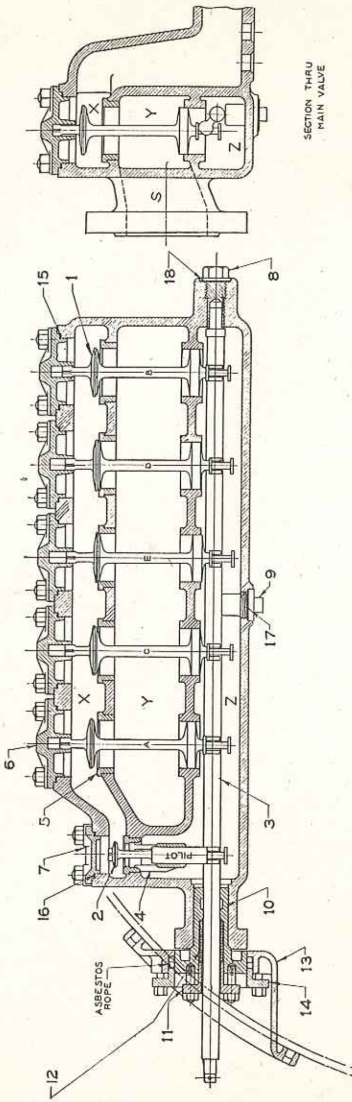


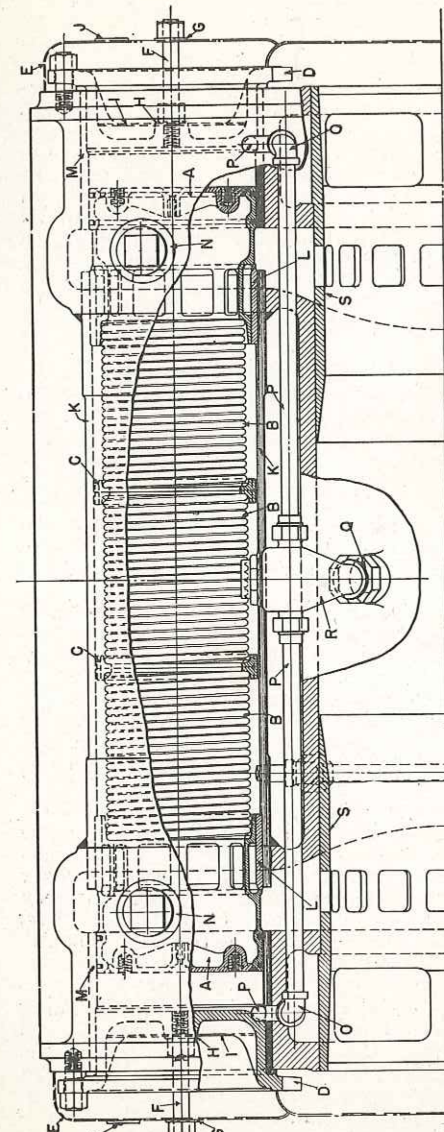
FIG. 8.
Multiple Throttle.

When the throttle lever is moved from the open to the closed position, the main valves close in the reverse order, the pilot valve closing last. Leakage past the balancing pistons immediately releases the steam from the balancing chamber as the pilot valve closes.

MODIFIED WAGNER BY-PASS VALVE

The modified Wagner by-pass valve shown in Fig. 9 is applied to some locomotives operating in mountainous territory where it is necessary to drift locomotives long distances on descending grades. The function of the modified Wagner by-pass valve is to permit drifting locomotives with the main throttle closed tight. The by-pass valve opens automatically when the throttle is closed and permits free passage of steam, vapor or air from one side of the piston to the other when the locomotive is drifting without drawing any gases from the smoke box into the cylinders. The by-pass valve saves considerable steam which results in fuel saving, as it is not necessary to use any steam to cushion the cylinders while drifting locomotive.

When a locomotive equipped with a modified Wagner by-pass valve is drifted, the main throttle must be shut tight. Unless the throttle is closed tight, the by-pass valve will not open.



A-VALVE
B-SPRINGS
C-SPRING SPACERS
D-HEADS
E-HEAD COVERS
F-HEAD STUDS
G-HEAD STUD WASHERS
H-HEAD STUD WASHERS
I-HEAD LAGGING PLATES
J-WARNING PLATES
K-HOUSINGS
L-INNER BUSHINGS
M-OUTER BUSHINGS
N-PLUGS
O-3/4" ELLS
P-3/4" PIPE
Q-1 1/4" PIPE CONN.
R-STEAM VALVE
S-VALVE CHEST BUSHINGS

Cylinder By-Pass Valve Assembly.

List of Parts

FIG. 9.

FRONT END AND DRAFT APPLIANCES

The proper and economical use of fuel depends to a large extent on the correct arrangement and maintenance in their respective positions of all parts of the drafting and spark arresting appliances. Given a fuel and a draft arrangement to get the best results from the fuel, it is then the enginemen's part in the proper combustion of fuel to see first that the locomotive is properly handled and performs the maximum amount of work from the steam produced, and that the firing is regulated in accordance with the requirements for steam. Experience shows that a locomotive to be drafted to the best advantage should be a free steamer and have a little margin as to steaming qualities. This can be had only when all draft appliances are in good order and the engineer and fireman work in harmony with each other and with the work the locomotive is called upon to perform.

Three methods are employed to draw air into the firebox; the natural or stack draft, a mild forced draft, which is had by the use of a blower; and a stronger forced draft, which in the locomotive is produced by the exhaust steam escaping from the exhaust nozzle through the stack.

If the fire is clean the air will flow freely through the grates and sufficient air will be admitted to insure a complete combustion of the fuel. If the fire is clinkered or full of dead ashes, the air is held back and the locomotive lags for steam. A dirty fire causes an unusual pull on the fire door which tends to pull it shut.

The front end of a locomotive should be maintained absolutely air tight so that no air will be admitted to the smoke arch except that which passes through the grates and fire. Air admitted to the smoke arch tends to weaken the pull on the fire, or in other words, destroys the vacuum and diminishes the air supply to the fuel, causing a smoky, wasteful, slow burning fire instead of a bright hot smokeless fire. Air leaking into the smoke box many times causes fine cinders to burn there, which warps and burns the sheets.

Any steam leak, whether from steam pipes, exhaust pipe or nozzle tip joint, from superheater units or header, has precisely the same effect to weaken the draft action on the fire as air leaks admitted to the smoke arch; and a defect of this kind, no matter how slight, should not be permitted to continue after it has been discovered. They are all wasteful, annoying and progressive, that is, they get worse and like many other defects, can usually be most conveniently and cheaply remedied at the time they are discovered and before they cause a failure for steam.

When difficulty is experienced on account of poor steaming with a locomotive that has established a reputation as a good steamer, or one which has been steaming properly for some time, the draft appliances should be examined. If found to be in good condition and in the same position when locomotive was steaming properly, no change should be made, and such other condition as is causing locomotive to steam poorly should be located.

The front end being in the same condition as when the locomotive was steaming well, cannot be improved and should not be disturbed. The engineer should determine if the locomotive is being properly handled and fired properly, that the quality of fuel is such that no difficulty should be experienced if properly fired. The locomotive may be a good steamer and the method of handling or firing may be at fault.

Fig. 1 shows the arrangement of a standard coal burning locomotive front end.

The extension front end or smoke box shown in Fig. 1 differs from the older type in that more room is provided for the draft plates and superheater elements.

Fig. 1 also shows the usual location of the petticoat or as it is often called, the lifting pipe, in the modern heavy locomotive. The petticoat pipe is considered as an extended stack, that is, it is practically an extension of the smoke stack into the smoke arch, and is usually of the same diameter as the inside of the stack. There is not sufficient clearance for roundhouse doors, tunnels, bridges, etc., to permit the application of a long stack on top of the smoke box, and it has been found entirely practical to lengthen the stack by extending it into the smoke arch and reducing the height of the stack outside.

BLOWER

In order to provide a draft through the firebox and flues heavier than that of the natural draft of the boiler a pipe is connected to the steam space of the boiler in the cab, having a valve located in same for the purpose of controlling the flow of steam through the pipe. This pipe leads to the front end of the boiler and through the side of the smoke box, its end being located so that as steam passing through the pipe is discharged from one or more jets, the steam is blown up through the smoke stack. This action of the steam drives the air out of the smoke stack and smoke box, creating a draft much in the same manner as that created by the steam passing out through the exhaust nozzle. Such an arrangement is called a blower pipe, and is shown in Fig. 1, number 207. In some locomotives, however, a coil of pipe surrounds the nozzle tip, having a series of holes or jets so that as steam pressure is admitted to the coil from the blower steam pipe, the steam jets pass out the smoke stack drawing out the air and creating a draft.

TABLE TYPE GRATES AND ASH PANS

Fitted into the firebox at the bottom and attached to the mud ring is a frame which supports the fire grates. These fire grates are usually of the rocking type, about 9 to 11 inches wide.

Each section of the grate consists of a heavy plate resting in the grate frame at each side, and having a series of holes through plate for admission of air. Extending below the grate is an arm which attaches to a rod extending back under the cab deck. This rod is connected to a shaker post reaching up into the cab, the shaker post is moved back and forth with what is called a shaker bar, so constructed that it can be fitted to the shaker post. As the shaker post is moved back and forth, the connecting rod leading to the grates is also moved back and forth, carrying with it the arm attached to the grate, causing the grates to be rocked. A sufficient number of these grates are applied to reach from one end of the firebox to the other. The grates are so located that they set close together but do not touch each other. The system of grates are all connected to the connecting rod. A locking arrangement is provided in the cab for securing the shaker post in position when the grates are all in their normal or level position. See that the grates are level and the lock is used after shaking, if the grates are not level the fire falls through badly.

At one end of the firebox in some cases is what is called a dump grate. This grate is usually of the same width or wider than are the rocking grate sections. This grate, however, has its shaft located at one side instead of in the center, so that if it is allowed to drop down an opening equal to the width of the grate would be provided, in the same manner as an ordinary trap door. This grate also has an arm extending underneath which is attached to a connecting rod leading back under the cab deck, and a post or shaft provided so that it may be raised or lowered. The purpose of this grate is to provide an opening large enough to permit clinkers and other refuse being cleaned out of the firebox in case such refuse cannot be disposed of by shaking the rocking grates.

For large wide fireboxes it is impractical to provide grates long enough to reach the entire width of the firebox, consequently a supporting frame is placed lengthwise of the firebox at the center. A system of grates is then installed on each side of the center frame, as shown in Fig. 10.

In order to reduce the difficulty of shaking the grates, half the grates on one side are connected to a connecting rod and shaker post, and the other half on the same side being connected to another connecting rod and shaker post. The grates on the opposite side are connected up in this same manner, so that when shaking the grates the fireman is required to rock only one-fourth of the total number of grates at one time.

Grates and Grate Rigging.

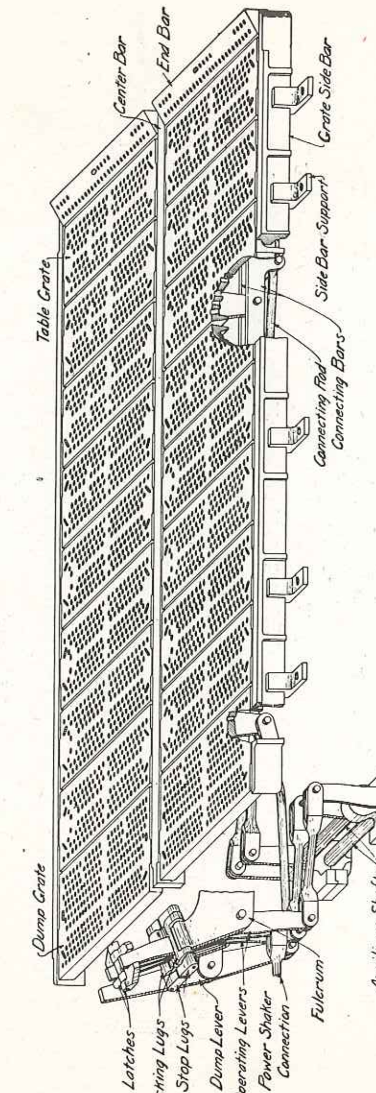


FIG. 10.
Round Hole Table Grate Arrangement.

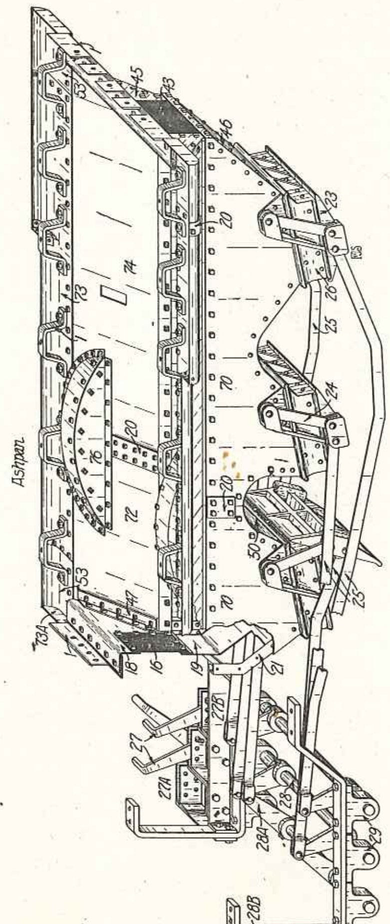


Fig. 11.
Ash Pan Arrangement.

ASH PANS

Below the grates is the ash pan, which serves to catch fire and cinders falling through the grates. It is provided with openings in the bottom through which the ashes may be dumped when it is desired to clean the ash pan.

Fig. 11 shows an ash pan commonly used on locomotives.

In Fig. 11 the slides for dumping the ash pan are operated by hand. Care should be taken after dumping the ash pan to make sure that the slides are properly closed and the locking pins are applied to hold the slides in a closed position. If slides are not kept closed tight fire may be dropped when fire hazard exists and damage occur. Do not allow fires to burn in the ash pan. If a quantity of burning coal is allowed to remain in the ash pan without wetting down, the metal sheets are badly burned and warped, and grates are liable to be burned. It is therefore advisable to wet down the ashes in the ash pan if much fire is present and it is impossible to dump the ash pan at that time. Do not hammer the sides of the ash pan excessively with the shaker bar or coal pick, this bends the sheets out of shape and loosens the joints so that the ash pan drops fire. See that ashes are kept pushed down into the pan and do not allow an accumulation of ashes around the edge of the pan at the mud ring. This shuts off the air supply and affects the steaming qualities of the locomotive.

PRIMING AND FOAMING

Priming is the carrying over of water from the boiler to the superheater units and cylinders of a locomotive. Priming may be caused by an abrupt drop in pressure, a too high rate of evaporation, or insufficient steam space, the result of carrying water level too high. All of these are influenced to a considerable extent by the concentration of objectionable salts in the boiler water.

Before giving the cause of foaming, it may be well to give a brief explanation of one of the principal characteristics of water, which is its expansive and contractive qualities under changes in temperature.

Water at a temperature of 39 degrees Fahrenheit weighs more per cubic foot than at any other temperature, either colder or warmer. At 39 degrees Fahrenheit water is at its greatest density, and from that point of greatest density it expands and becomes lighter, whether by getting colder and freezing or by heating and boiling.

A cubic foot of water at 60 degrees Fahrenheit weighs about 62 pounds, while a cubic foot of water at 390 degrees, representing 210 pounds boiler pressure, weighs 54 pounds. A cubic foot of water at 60 degrees temperature occupies 1,728 cubic inches of space, while if heated to a temperature of 390 degrees at 210 pounds boiler pressure, it will expand to a volume of 1,952 cubic inches, or 224 more cubic inches than it occupies at 60 degrees, an increase in volume of about 13 per cent. A 3160 class locomotive boiler, as shown in Fig. 4, will require about 4,000 gallons of water when filled to the bottom of the water glass. If a 3160 class boiler is filled with water up to the bottom of the water glass (or just where the water is visible in the glass), at a temperature of 60 degrees Fahrenheit, and then this water is heated to a temperature of 390 degrees at 210 pounds boiler pressure, the expansion of the water will raise the visible water level in the water glass about 7 inches, occupying a space equal to about 4,500 gallons. It is this expanding feature of water which establishes circulation, the hot water from the heating surface rising and being displaced by heavier cooler water.

Water is an almost universal solvent and readily takes into solution such solids as alkali salts, which are chloride of soda (common salt), sulphate of soda (Glauber salts), and carbonate of soda (soda ash). It also holds in suspension scale forming solids such as carbonate of lime, sulphate of lime, silica or magnesia. The water in form of rain passing through the earth's surface and underground streams comes in contact with these various solids which are soluble in water. The alkali salts referred to above concentrate in the water in the boiler to the extent that the water changes to a syrupy, or more or less slimy, soapy consistency. Water of that character will cause foaming, and especially so when there is also in suspension some of the scale-forming solids. The scale-forming solids are precipitated on the interior heating surface of the boiler at temperatures above 212 degrees Fahrenheit. The scale-forming solids in the presence of soda ash are likely to form sludge and be held in suspension in sufficient quantities to discolor the water and be visible in the water glasses. Sludge or suspended matter in the boiler water will materially increase the foaming tendency. It is, therefore, important that the water in the boiler be kept as free as practical from suspended matter by the proper use of blow-off cocks.

The rapid forming and upward flow of steam or gas bubbles from the heating surfaces, increase or diminish according to the amount of steam being generated.

When a locomotive is working and the throttle is closed, there is an instantaneous reduction in the amount of bubbles being produced, and a corresponding lowering of the water level as indicated by the water glass or gauge cocks. When a locomotive is standing with steam pressure in the boiler, and the throttle is opened, there is an instantaneous increase in the production of bubbles, which raises the water level as shown by the gauges. To minimize the liability of foaming or priming, use the blow-off cocks frequently and use anti-foam compound as prescribed. Use the feed water pump or injector steadily but do not flood the boiler, and above all, do the right thing at the time it should be done.

The feed water pump or injector should be started 5 to 10 seconds before throttle is opened when starting a locomotive from state of rest, or after drifting locomotive with throttle closed.

USE OF BOILER COMPOUND

Anti-foam compound should be used in time to prevent foaming. This should be done before foaming commences, and when compound has been applied, the water in the tank and boiler should be under treatment continuously, the former by applying compound every time water is taken, and the latter by working feed water pump or injector continuously while the locomotive is working. In this way a continuous supply of compound to the boiler is maintained. With compound used as above and proper use of blow-off cocks, foaming can usually be controlled.

The best results are obtained by keeping the water at a uniform mixture, viz., when one-half tank of water is taken, use one-half the amount of compound required for a full tank, etc. Compound should be thoroughly mixed with hot water before being placed in the tank. One pound (pint) to each 15,000 gallons of water taken should be used unless otherwise authorized.

USE OF BLOW-OFF COCKS

The principle that should govern in blowing out a boiler to prevent foaming is that the sludge and suspended matter in the boiler water should be blown out and replaced with fresh water from the tender. The sludge and suspended matter should be blown out of the boiler without diluting with fresh water from the tender.

When the boiler is foaming, or it is thought it is getting near the foaming point, and a stop is to be made, use both blow-off cocks working intermittently, and blow out as much water as can be spared down to an inch or half an inch of the bottom of the water glass. If it is necessary, on account of the boiler popping, to cool it by using the injector a little, that is the proper thing to do. Filling boiler full of water at one time when water is low causes great differences in temperatures between the lower and upper parts of boiler, and the liability of starting flues and staybolts leaking is greatly increased.

Blow-off cocks should be opened intermittently from both sides if possible and under no circumstances should be held open continuously. The reason for this is that it is necessary to eliminate the water in the water leg and lower parts of the boiler, which is heavily charged with suspended matter, and the opening of blow-off cocks at intervals gives time for the sludge to collect again around the blow-off cock opening in the boiler. If they are held open for long periods, a column of water forms from the upper parts of the boiler which holds back the water on each side of this column.

Blowing out of locomotive boilers should be started at the beginning of the trip and continued at frequent intervals regardless of any tendency to foam. A modern boiler holds about 5,000 gallons of water, and at temperatures above 260 degrees Fahrenheit most of the scale-forming solids are either deposited on the heating surfaces in the form of scale, or form sludge which will settle to the bottom of the boiler.

Opening the blow-off cocks a few times at convenient intervals at the beginning of the trip discharges a large percentage of this sludge (or suspended matter). In foamy water districts the maintaining of boilers free from sludge insures much better performance and greater freedom from foaming for the reason that when sludge is present in the lower part of the boiler, any rough handling or unusual hard work has a tendency to disturb and cause it to raise and mix with the water above. This almost invariably results in foaming, which will continue until the sludge is settled again or is blown out. The amount of water to be blown out is much less if the blow-off cocks are opened soon after starting the trip, than is the case if no water is blown out before foaming actually begins. The engineer should know the peculiarities of the water on his district, and where the water is liable to start foaming, he should prevent it by proper use of blow-off cocks, keeping the water in the boiler free from suspended matter and under the influence of compound.

It should be borne in mind that the cooler water from the feed water pump or injector goes to the bottom of the boiler and if blow-off cocks are used when feed water pump or injector is working, less of the sludge is blown out than will be the case with the feed water pump or injector shut off. It is desirable to use the blow-off cocks on descending grades when the locomotive is being operated with main throttle in drifting position or shut off entirely. On descending grades it is good practice to shut the water pump or injector off before using blow-off cocks, and wherever possible this should be done.

When the locomotive is standing and it is necessary to increase the water supply in the boiler, not more than one inch should be injected at one time. Water should be supplied, if possible, when locomotives are moving to or from a train, or while handling a train. No chances should be taken of damaging the boiler on account of low water, but it is expected the proper use of feed water pump or injector will be followed whenever conditions will permit. Any engineer, fireman or hostler who accustoms himself to using the feed water pump or injector only when the locomotive is working will find there are very few occasions when it will be necessary to vary from this practice.

Locomotives coming into a terminal should arrive with a full glass of water so that when taken from the train to the roundhouse a half glass or more can be blown out without any water being taken into the boiler, but no additional filling of the boiler and blowing down should be done, as this puts too much cold water into the boiler, which settles to the lower part and sets up unbalanced strains resulting in leaks of stay bolts and flues.

Concentrations of soluble solids are run on boiler samples at most terminals. A definite maximum boiler concentration should be established for each terminal and posted, and an effort made by engine crews to do just enough blowing on the road so that the boiler concentration on arrival of the loco-

motive at its terminal will be below the maximum concentration and thus keep the need of terminal blowing at a minimum.

SIGNAL FOAM-METER ELECTROMATIC BLOWOFF

The Signal Foam-Meter gives signal light indications when the invisible high water level commonly referred to as "foam" reaches predetermined levels in the steam space of the boiler. The one inch Electromatic Blowoff Valve operates automatically to prevent the invisible high water level or foam from reaching an excessively high point in the steam space.

Two insulated electrode rods of different lengths protrude from the boiler shell into the steam space above the crown sheet. The long electrode ends about even with top of water glass level. The short electrode ends about five inches above the water glass.

If foam or high water comes in contact with the long electrode for about twenty seconds, the bottom lamp bulb lights and the Electromatic Blowoff Valve opens. When the foam or boiler water drops away from the long electrode, enough of the concentrated boiler water has been removed, and the bottom lamp bulb will go out and the Electromatic Blowoff Valve will close. (The twenty seconds delay is to prevent the operation of the Blowoff when foam or water splashes against the electrode.)

A steady bottom light indicates a safe operating condition, the foam or invisible high water filling only a portion of the steam space. If, because of some unusual operating condition, foam should increase in the boiler water to where it touches the short electrode, the top lamp bulb will light, indicating the foam as practically filling the steam space and automatic blowoff cock will operate immediately. A steady top light should be prevented by use of the regular manually operated blowoff cock, or by a slight easing off of the throttle to reduce the foam to a safe level, or increasing pump supply to reduce boiler concentration.

The Blowoff Valve located near the back corner of the mud ring is opened by air from the small electric valve located near the instrument case in the cab. When the bottom lamp bulb lights, the electric valve opens to let air flow to the air piston in the Blowoff Valve. This in turn opens the Blowoff Valve. The Emergency Shutoff Valve in the Blowoff Valve should always be open while the locomotive is in service.

The electric toggle switch under the signal box, controls the operation of the Blowoff Valve. The switch should be turned on while the locomotive is in service. It should be turned off at terminals, or at any other time when the operation of the Blowoff Valve might not be desirable.

When it is desired to blow out the boiler on level or ascending grades ahead of time so that the Foam-Meter will not blow as long later on when tipping over grades or when water level in boiler will not permit blowing out, operate Foam-Meter equipment manually along with the hand-operated blow-off cocks opened alternately with short blows.

Use hand-operated blow-off cocks on all locomotives when safe foam light shows after taking untreated water or water treated by wayside internal treatment, and in addition the Foam-Meter equipment should be used manually along with the hand-operated blowoff cocks on all long descending grades.

Never carry less than the recommended water level, which is from 2 to 4 inches in gauge glass on level track, 3 to 6 inches on ascending grades of 1.25 to 3 per cent, and 6 inches on ascending grades of 3 per cent or over, with the object of keeping the Foam-Meter from operating automatically because the foam accumulates more rapidly and will in time contact the long electrode and blow longer than if the proper water level had been maintained.

Always pump boiler in ratio to steam demand and have water going into the boiler just before starting, which will keep the water from rising excessively in the boiler and reduce the time the Foam-Meter is open after starting. This method will give full value of anti-foam compound when used and reduce the blowing when not using compound. Erratic pumping of the boiler results in more foaming troubles than any other single cause.

Avoid filling boiler when standing and the injector should be used in cases where it is necessary to put water in the boiler while drifting or standing.

Always report any improper operation of the Foam-Meter equipment so that repairs can be made immediately.

ARCH AND CIRCULATING TUBES IN LOCOMOTIVE FIREBOXES

Fig. 1 also shows the general location of arch tubes in a locomotive firebox. While the arch tubes are designed to support the brick arch its function is primarily a circulation tube to convey the cooler water from the lower parts of the boiler to the upper parts. As the water in the tube absorbs the heat from the fire it becomes impregnated with steam bubbles, expands and becomes lighter and as it becomes lighter ascends through the tube and circulation is established. As the hot water passes through the tubes it is replaced with cooler water from the lower parts of the boiler.

The purpose of installing brick arches in locomotive fireboxes is to secure greater fuel economy with increased combustion efficiency.

The brick arch increases the length of the flameway by forcing the products of combustion from the front of the firebox to the back, then up over the arch and forward under the crown sheet, and along the side sheets to the flue sheet into the flues.

Heat is absorbed by the arch, and as it reaches the highest temperatures of combustion serves to ignite volatile matter given off by the fuel that otherwise might escape unburned out through the flues. Less black smoke and soot are emitted.

Cinder losses are reduced, particularly on stoker-fired locomotives, where a large percentage of fines exist in the fuel used, by the finer particles of fuel being burned as they are forced through the intense heat under the arch. The effect is higher evaporation and increased steaming capacity of the locomotive, with a reduction in fuel consumption.

THERMIC SYPHONS

The functions of this device are to increase evaporation; to increase circulation; to provide a substantial support for the brick arch; and to reduce maintenance of firebox sheets and flues through the effect of "Syphon" induced circulation.

The syphon is made of an approximately square plate of ⅜-in. firebox steel folded over a 6¼-in. mandrel along a diagonal in such a manner as to form a triangular water leg—see Fig. 12. The sides of the water leg are drawn together sufficiently to provide a 3-in. water space and they are stayed in the conventional manner. The principal dimensions of the Syphon vary according to the size of the firebox to which it is to be applied.

The bottom or bulge portion of the Syphon being circular in form is self-supporting and at the lower end is extended out from the body of the Syphon to form a cylindrical intake neck 6¼-in. inside diameter. The neck is connected to a diaphragm in the tube sheet.

The front vertical edges of the sheet are flanged inwardly and joined by fusion welding. The welded seam extends from the top of the Syphon down to the end of the neck, and is supported throughout its length by staybolts. The upper edges of the sheet are flanged out to an overall width of about 12-in. and to a contour to coincide with the firebox crown sheet, the flanges being drilled to suit the radial stay locations—see Fig. 13. In this view it will be observed that one row of radial stays passes through each flange of the Syphon itself and that the welds come between these rows and the next rows of radials which are in the body of the crown sheet. By this construction the stress is supported by the radials, thereby relieving the welds.

The number of Syphons which can be installed in a locomotive firebox is governed by the width of the firebox. There may be one, two or three Syphons. Syphons are also applied in combustion chambers 36-in. or more, long. One or two may be used. The rule which regulates this matter is that there shall always be ample room for a man to work around and between the Syphons and that there shall always be sufficient space left between the front of the Syphons and the flue sheet for a man to get in and work the flues.

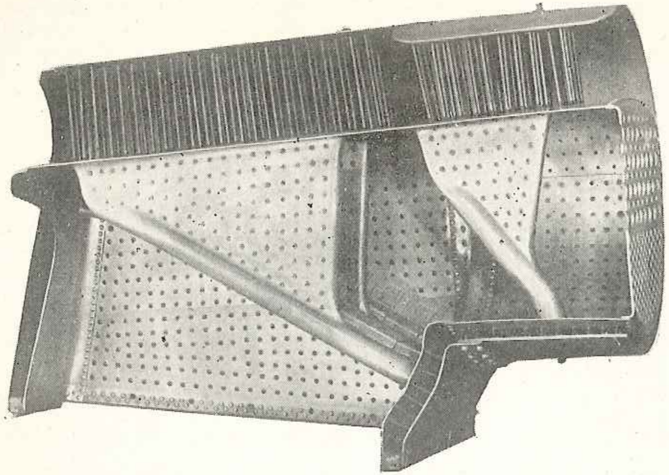


FIG. 12. Typical Side View of Syphon in a Coal-Burning Locomotive.

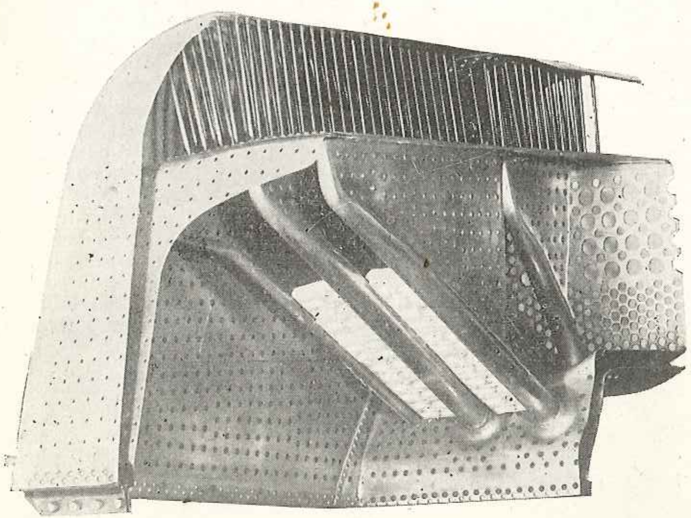


FIG. 13. Typical Rear View of Syphon in a Coal-Burning Locomotive.

THE CIRCULATOR

The function of the circulator is to increase circulation in the side water legs of the firebox and provide a substantial brick arch support. The application of a circulator in the firebox of a coal-burning locomotive is shown in Fig. 14, and an oil-burning locomotive in Fig. 15.

COMBUSTION

The railroads burn approximately 25 per cent of the bituminous coal produced in the United States, and coal tonnage approximates about one-third of the combined freight traffic of all the railroads. The fuel bill for this Company alone is more than $15,000,000.00 annually. This emphasizes the necessity for a proper interest and effort toward fuel saving.

Bituminous coal usually contains from 35 to 50 per cent fixed carbon, 35 to 45 per cent volatile matter, from 3 to 15 per cent moisture and 8 to 15 per cent ash.

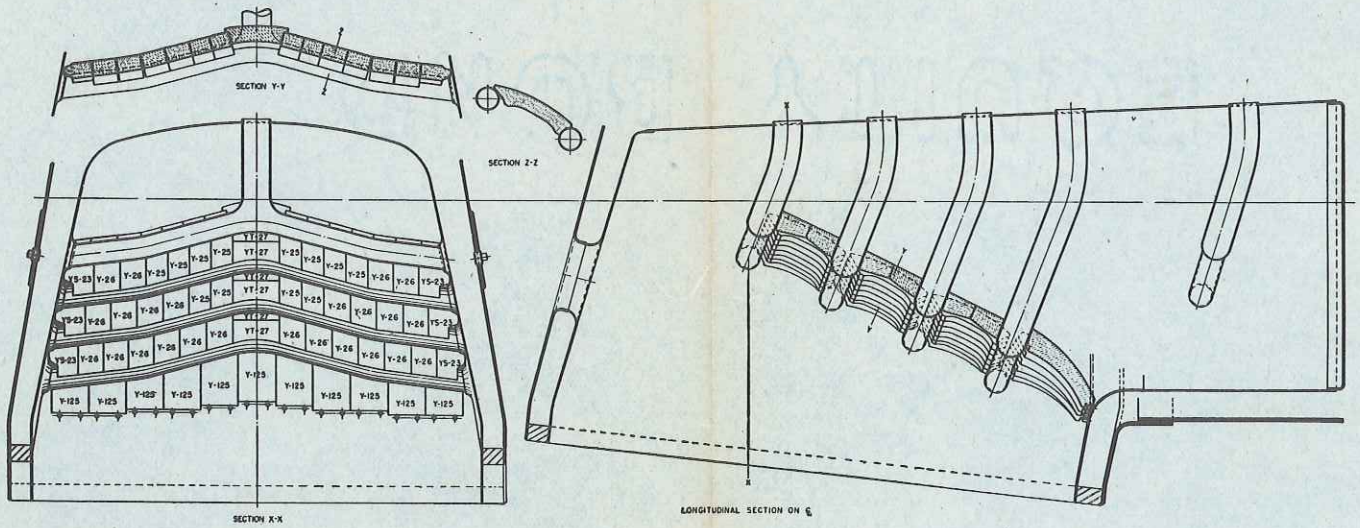
The volatile matter is composed usually of carbon, hydrogen and oxygen in chemical combination and it is the volatile matter that is driven off when heated to sufficient temperature.

When a bed of fire is obtained from which the gases have all been driven off, if sufficient air is passing through the fire the carbon will burn in a white incandescent mass with but lttle flame. Then when coal is added, if fed in small quantities and spread out over the fire and the temperature in the firebox is high enough to break down and separate the different substances, the gases will be driven off and will burn, in the form of flame and will be entirely consumed in the firebox.

If on the contrary, coal is added in heavy quantities in any part of the firebox, it has a quenching or cooling effect on the fire, also, temporarily shuts off the full flow of air through the fire where the heavy quantities are placed, which deprives the gases raising from the coal of sufficient oxygen to support combustion and they pass out of the firebox unburned in the form of black smoke.

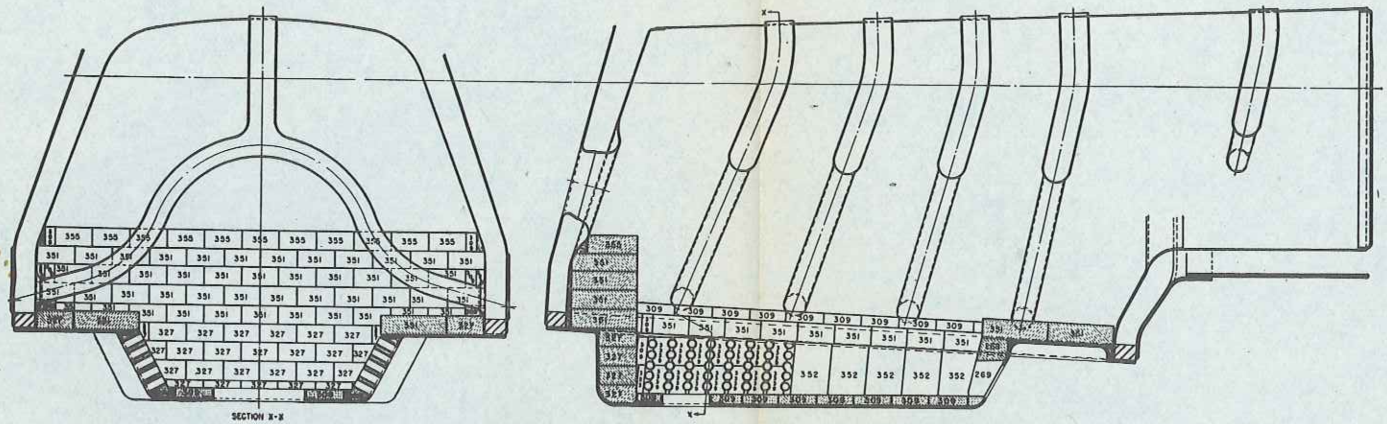
Three things are essential to the proper combustion or burning of fuel in a locomotive firebox. They are, the fuel to be burned, the oxygen which is a supporter of the combustion, and the igniting temperature of the fire. The latter being necessary to expell the gases contained in the fuel in order that they might unite with the oxygen in the air. In order then to provide for proper combustion it is necessary that a fireman be familiar with the elements contained in the atmosphere, and the various fuels, and in a measure concentrate his attention upon the relation of fuel, oxygen and igniting temperatures.

Oxygen is a part of the air, representing about one-fifth of it by volume. In order to obtain an ample supply of oxygen for the proper combustion of the fuel placed in a firebox, it is necessary to draw through the fuel bed a quantity of air which is equal in volume to five times the volume of the oxygen required. This must be accomplished through the action of the draft through



Arrangement of Circulator in a Coal Burning Locomotive.

FIG. 14.



Arrangement of Circulator in an Oil Burning Locomotive.

FIG. 15.

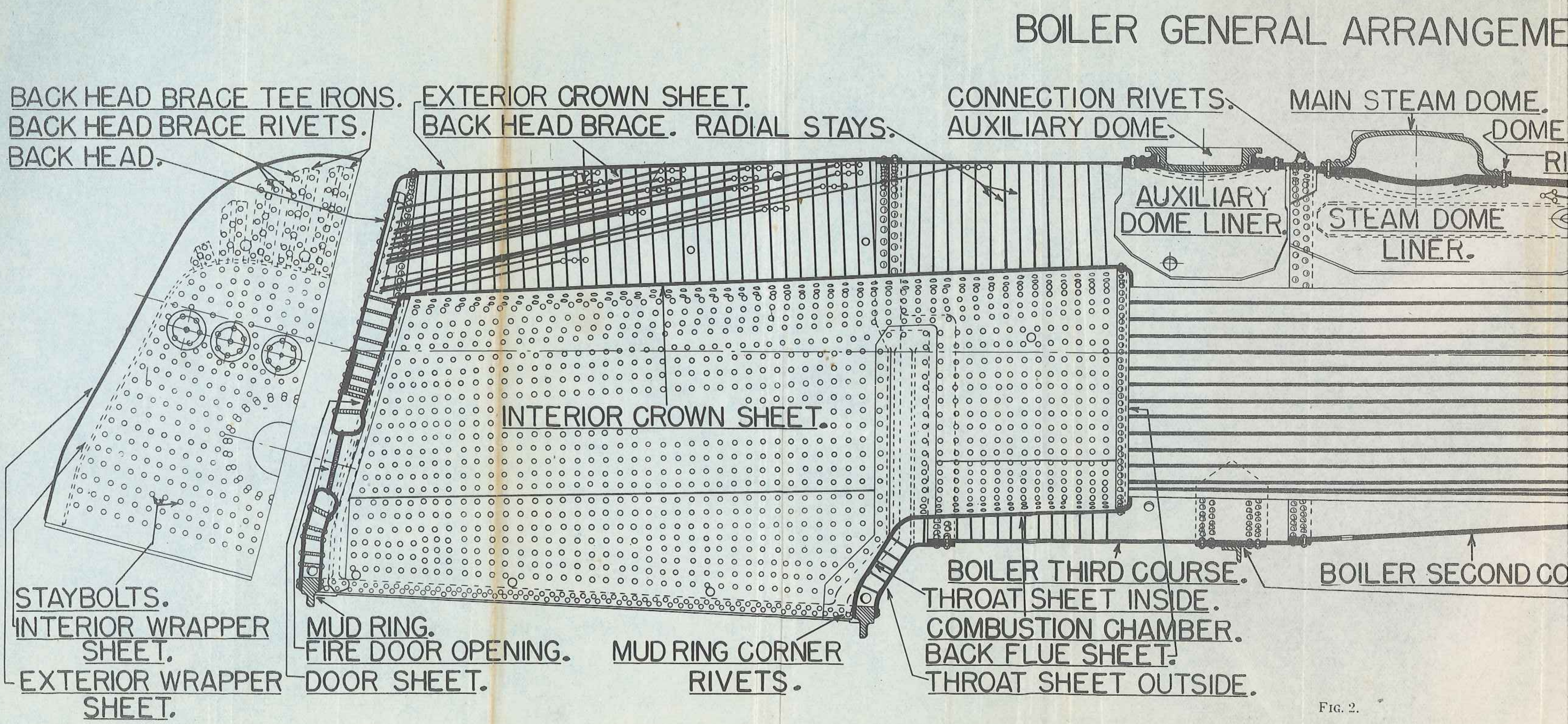

BOILER GENERAL ARRANGEME
BACK HEAD BRACE TEE IRONS.
BACK HEAD BRACE RIVETS.
BACK HEAD.
EXTERIOR CROWN SHEET.
BACK HEAD BRACE.
RADIAL STAYS.
CONNECTION RIVETS.
AUXILIARY DOME.
MAIN STEAM DOME.
DOME
AUXILIARY DOME LINER.
STEAM DOME LINER.
INTERIOR CROWN SHEET.
STAYBOLTS.
INTERIOR WRAPPER SHEET.
EXTERIOR WRAPPER SHEET.
MUD RING.
FIRE DOOR OPENING.
DOOR SHEET.
MUD RING CORNER RIVETS.
BOILER THIRD COURSE.
THROAT SHEET INSIDE.
COMBUSTION CHAMBER.
BACK FLUE SHEET.
THROAT SHEET OUTSIDE.
BOILER SECOND CO

FIG. 2.

R GENERAL ARRANGEMENT

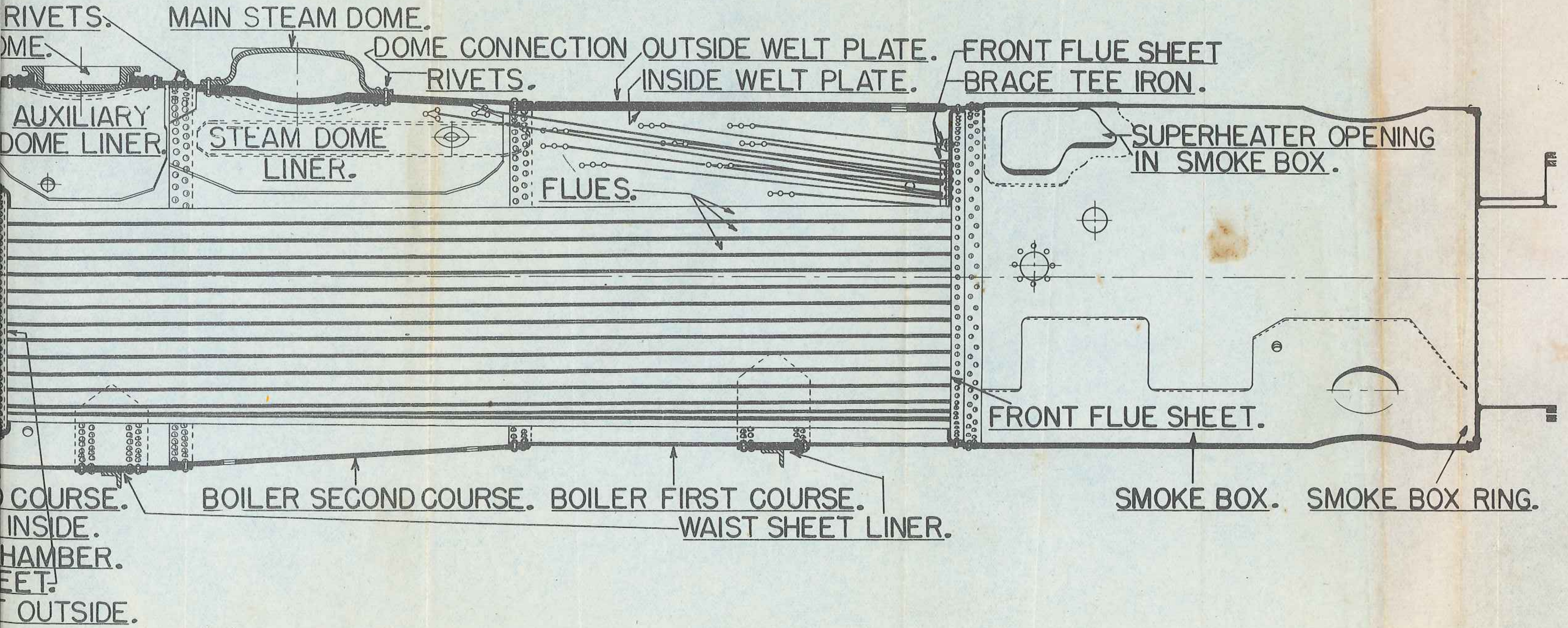


FIG. 2.

the smoke box and flues; and in order to permit it to be accomplished, it is necessary to provide sufficient openings through the ash pan and grates, and keep the fire in a condition that will permit free passage of air through the entire fuel bed on the grates.

The process of burning fuel in a locomotive firebox is the uniting of oxygen, which is a gas, with the gases contained in the fuel. In order to cause the gases in the fuel to mix with the gases contained in the atmosphere, it is necessary that the firebox temperature be sufficiently high to cause the gases to be expelled from the coal.

When coal is placed in the firebox the gases in the coal will be expelled with any temperature above 1300 degrees and will mix with the oxygen contained in the atmosphere. When the gases unite under these conditions heat is produced, from which steam is generated.

When these two gases unite under these conditions, heat is evolved and used in generating steam. If a sufficient supply of oxygen is present, a pound of carbon will burn to form a colorless gas called carbon-dioxide, and enough heat will be evolved to convert 12½ pounds of water into steam, the water to begin with being at a temperature of 32 degrees. If, however, the supply of oxygen is insufficient, then another colorless gas will be formed, called carbon-monoxide and only four pounds of water will be evaporated under similar conditions, that is, with the same carbon to be burned one may get its full heat value, or less than one-third, depending upon the supply of oxygen.

The result of placing large quantities of coal in a firebox at one time causes a greater quantity of gases to be liberated from the fuel than can properly mix with the oxygen passing up through the grates. Some of these gases pass off unburned, and when large quantities of coal are placed in the firebox, it is impossible to properly liberate and burn the gases expelled. For example, if a scoop of coal is thrown in one pile on a hot fire the gases around the edges are driven off quickly, a little later the gases throughout the shovel full of coal are gradually expelled and burned. If, however, another scoop of coal is thrown on top of the first one before the gases have all been expelled, it simply smothers the gases under the second shovel full, causing a part of the coal to remain unburned. It also shuts off the free flow of air through the fire, causing more or less coking and clinkering of the coal, which later on contributes to the labor and annoyance of the fireman, which could have been prevented had he avoided bringing about such a condition.

It must be remembered that more than half the fuel consumed in a locomotive firebox is consumed as gases. Therefore, if these gases are being liberated from the fuel in quantities greater than can be properly mixed with the oxygen passing up through the grates, some of the gases will escape unburned. Heat is thus expended in breaking down the coal and liberating the gases and then the best part of the fuel is simply thrown away.

While it is impractical to maintain absolutely perfect combustion in a locomotive firebox, due to the manner of supplying the fuel at irregular intervals, and in varying quantities, variation of grades, loads, and speed, which requires a variation in the amount of steam used and consequently fuel consumed; it should be possible to evaporate five to seven pounds of water to one pound of bituminous coal burned. Ordinarily it requires twelve to eighteen pounds of air to supply the amount of oxygen to consume the gases expelled from one pound of soft coal. A pound of air occupies a space of thirteen cubic feet. Taking twelve pounds of air, the lowest rate of air consumption for one pound of coal, multiplying by 13 cubic feet gives 156 cubic feet of air used for each pound of coal burned. Ordinarily this would require about 30,000 cubic feet of air for each ton of coal burned. The above emphasizes the necessity of unrestricted air admission through the grates. Anthracite coal contains a higher per cent of carbon than bituminous coal, and burns with a much smaller flame, because more of the total composition of the coal is consumed as carbon.

FIRING PRACTICE

The fireman should see that the fire is properly prepared before starting, and avoid forcing the fire too much with the blower to bring about this condition. The fire should be built up gradually by scattering the coal evenly over the grate surface and in light quantities. He should also see that he has proper tools and appliances to care for the fire on the road and the grates in proper working order. The grates should not be shaken too soon after leaving a terminal, the idea being to allow a slight accumulation of ash next to the grate, if possible, before they are shaken at all. The first time the grates are shaken, they should be shaken very lightly.

The fireman should cultivate the habit of proper and regular firing. He should learn to fire as lightly as possible and maintain an even fire, scattering the coal as thinly over the grate surface as conditions will permit, opening and closing the door between each scoop of coal. Do not take it for granted that because it is necessary at times to fire the locomotive seemingly heavy, such as might be the case in ascending grades with heavy trains, or where the locomotive is being worked unusually hard for some particular reason, that there is not a large percentage of the time that the locomotive may be fired much lighter. The fact is, that in most localities the locomotive may be fired regularly and lightly for a greater part of the distance over a division. To obtain the best results the locomotive should be fired as light as possible under all conditions, and as regularly as possible, maintaining as thin and as clean a fire as the conditions will permit.

When the fire becomes too heavy or is clinkered, which of course brings about a low temperature in the firebox, or on account of there not being sufficient air admitted through the fire, the fire will not burn to a white heat, a fire in such condition is usually termed a red fire. It is generally impractical to attempt to regulate the amount of air admitted to the firebox by opening the firebox door. If the supply of air admitted above the fire could be exactly regulated by opening the firebox door, it would many times serve a very useful purpose. However, air admitted through this source is not sufficiently distributed among the fuel gases to produce proper combustion, and being admitted in a cold state it chills the firebox and flues.

Care should be taken that too much air is not admitted to the firebox by allowing holes to form in the fire. This tends to rob the balance of the grate area of its share of the air and permits the gases to be carried out of the firebox unconsumed. Air admitted through a hole in the fire is relatively cold and chills the firebox sheets and flues. Clinkers will be formed if coal is placed over the bare spots on the grates. It is possible, of course, to admit too much air if the fire is too thin, or by leaving the firebox door open if the locomotive is working.

The air openings in ash pans should equal or exceed 14 per cent of the grate area. The grates used for burning bituminous coal should have openings of approximately 13 per cent of their total area. Defects in the grates or grate rigging, or excessive lost motion in the latter, should be reported promptly, to keep these parts in good repair. Remember that for each one shovel full of coal saved you are lessening your labors about three-fourths of one per cent per ton of the coal handled. Remember also that every man connected with the operation of trains is either a saver or waster of fuel.

In approaching stations or other points where stops are to be made, the fire should be burned down to prevent excessive black smoke. The emission of clouds of smoke when drifting is very annoying and discomforting to passengers and should not be permitted. On arrival at terminals the fire should be thoroughly burned out. Do not leave locomotives with heavy fires banked with "green" coal. The fireman should, on approaching terminals, endeavor to burn out all banks in the fire and have the fire in such condition that it may be cleaned without necessitating dumping large quantities of "green" coal.

When a fireman produces black smoke he does so because he is only partially burning the hydro-carbon gases and in proportion to the density and amount of black smoke passing out the stack will he be required to place more coal in the firebox. In other words, if he could maintain the steam pressure by making very little or no smoke, the amount of coal to be placed in the firebox would be considerably less than is the case where great quantities of smoke are produced. Black smoke is unburned carbon, mixed with a very high percentage of combustible gases and it therefore represents a considerable part of the coal that is valuable for heating purposes. It is also an indicator pointing to a loss. There is always a tendency toward loss of fuel in heavy firing on account of the large amount of gases expelled from the coal, and the temporary stoppage of the circulation of air through the fire just at the moment the gases are being expelled. Lighter firing and scattering the coal well over the grate

surface maintains a better circulation of air through the fire, the gases are expelled from the coal in smaller quantities, which provides for a better mixture of air with the fuel gases. To secure proper combustion of the gases expelled from the coal they must be mixed with sufficient oxygen immediately upon being evolved in order to burn properly.

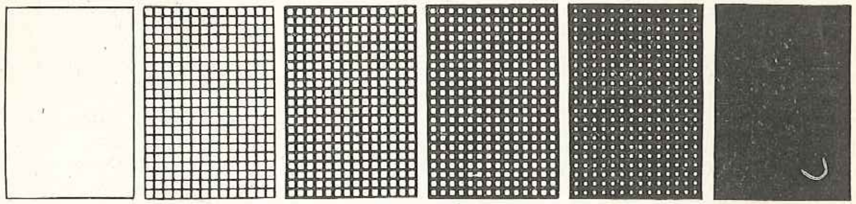


Fig. 16.

The Ringlemann Scale for Grading the Density of Smoke

The Ringlemann chart, Fig. 16, showing smoke density should be studied by enginemen. Numbers 0, 1 and 2, indicate good fuel performance. The numbers 3, 4 and 5, indicate poor, and when either, especially 4 and 5, show at the stack, it is either a case of poor firing or a defective locomotive. The fact is, good firing and good conditions will rarely show as dark as No. 2.

The blower should be used only heavy enough to clear up the smoke. One thing essential in reducing black smoke and securing economy in the use of fuel is for the engineer and fireman to work in harmony and co-operate with each other at all times. The engineer should realize that good results in the prevention of black smoke and also that proper firing cannot be obtained unless he works the locomotive as economical as possible, and keeps the fireman fully informed of changes that he can anticipate in the working of the locomotive. With the locomotive free from leaks and blows, and properly drafted for good steaming, there is no good reason why fuel consumption and black smoke cannot be reduced to a minimum.

RULES FOR GUIDANCE OF ENGINEERS, FIREMEN, HOSTLERS AND OTHERS WHO HANDLE OIL-BURNING LOCOMOTIVES

The following definition of terms pertaining to locomotive oil burning equipment is offered as an aid in the instruction of employes whose duties necessitate their being familiar with this equipment.

ATOMIZER. That portion of the burner which delivers a jet of steam for breaking up the oil into finely divided particles to aid combustion. The atomizer jet carries the particles of fuel oil from the burner into the burning zone.

BLACK SMOKE. Soot from partially consumed oil. A sign of poor combustion and poor firing.

BRICK WORK. Fire brick is used in lining the draft pan, in the construction of the flash wall, and for the protection of the mud ring and fire door and to retain heat.

BURNER. An appliance provided for atomizing fuel oil and delivering it to the firebox. The atomizer and oil port constitute the two compartments of the burner, and are cast in a single casting.

CARBON. A gray black accumulation formed in the draft pan of oil-burning locomotives due to improper combustion. This formation on the floor of the pan is due to improper adjustment of the burner or to obstruction on the floor of the draft pan, which deflects the flame travel and results in incomplete combustion. Carbon may also be formed by fuel oil too cold for proper atomization, and by too strong or too little atomizer jet.

CUT OUT VALVE. A valve in the oil line under the deck so located that from a position on the ground on the left side of the locomotive the oil passing to the burner can be shut off.

DAMPER. A metal door operated from a lever in the cab to regulate the admission of air into the hopper beneath the draft pan.

DRAFT PAN. A rolled steel or cast steel pan secured to the bottom of the mud ring which acts as a floor for oil-burning furnace and through which air is admitted and regulated for proper combustion.

FIRE DOOR. An opening in the back head of the boiler through which workmen may enter the firebox for inspection and to make repairs. It should be kept closed and locked while locomotive is on the road and under fire.

FIRING VALVE. A valve for the purpose of regulating the flow of fuel oil to the burner.

FIRING VALVE RIGGING. Reach rods and levers connecting the firing valve to the operating handle in the cab.

FLASH WALL. A fire brick wall in the draft pan toward which the fuel oil is delivered, and which assists in vaporizing and igniting the oil. The flash wall also directs the course of the flame.

FUEL OIL. The residue of crude petroleum after removing the lighter oils, such as gasoline and kerosene, by the methods used in refining crude oil.

FUEL OIL TANK. The sheet metal tank placed in the coal space of the locomotive tender for the purpose of carrying the fuel oil supply.

HEATER—DIRECT. A pipe extending through the top of the oil tank to within 2 inches of the bottom, through which steam is blown into the oil for the purpose of heating it quickly, and agitating fuel oil in the tank.

HEATER—INDIRECT. A heater located in the oil tank for heating the oil. There are two types of heaters used for this purpose. The coil type consists of a coil of pipe through which the steam passes without coming in direct contact with the oil. The drum type consists of a steel drum twelve inches in diameter and four to six feet long. Steel tubes 1½ inches in diameter are welded into a tube sheet located at each end of and welded to the drum. The oil is heated as it passes through the tubes without coming in direct contact with the steam. Some locomotives have indirect heaters outside of oil tanks, which are located below the oil tanks and on the front of the tenders. The oil enters the heater drum at the bottom and is heated by means of steam coils located inside of drum. The heated oil then flows to the burner through the oil feed pipe. Any oil or water vapors driven off the oil in this type of heater are vented back into the oil tank through a 3-inch vent pipe which is located on the front of the oil tank.

MANHOLE. An opening in the top of the oil tank for the purpose of filling the tank with fuel oil, and also for workmen to enter the fuel oil tank.

MEASURING ROD. A steel rod graduated in inches and gallons used for measuring the amount of fuel oil in the tank.

OIL PORT. That portion of the burner through which oil is delivered to the firebox.

OIL STRAINER. A netting or basket located in the manhole for collecting pieces of wood, waste, carbon, etc., in the fuel oil which are of such a size that they might stop up the oil line or burner, if allowed to enter the fuel oil tank.

OIL TANK VENT. An opening in the center of the manhole cover to relieve the oil tank of any accumulation of steam or gas pressure, usually provided with a pipe elbow to prevent dirt and refuse from entering and getting into the oil or clogging the opening.

PEEP HOLE. A small circular hole in the sanding hole cover through which the fireman may watch the action of the fire.

SAFETY OIL VALVE. A quick acting valve in the oil tank provided to shut off the flow of oil to the burner.

SAND SCOOP. A device for delivering sand to the sanding hole in the fire door for cutting soot from the firebox and flues.

SANDING HOLE. A circular hole in the fire door provided for sanding flues and admitting air over the fire.

SOOT. A black carbon formation which adheres to the firebox and flues, which is caused by incomplete combustion of the fuel oil. It acts as a heat insulator and reduces the boiler efficiency.

LOCATION OF EQUIPMENT

Figure 17 shows location of the various cab valves, tank fittings, and other oil-burning equipment. The numbers and names of the various parts of the oil-burning equipment are shown on the drawing, and it is essential that employes be familiar with all parts of the equipment before studying the instructions which follow.

Figure 18 shows the firebox in section to show the draft pan, brick work and air openings.

To Use Blower. Open valve No. 1.

To Deliver Steam to Atomizer. Open valve No. 2.

To Deliver Steam to Indirect Heater. Open valve No. 4 and turn handle down on three way valve No. 11.

To Deliver Steam to Direct Heater. Open valve No. 4 and turn handle up on three way valve No. 11.

To Drain Water out of Oil Tank. Open valve No. 8.

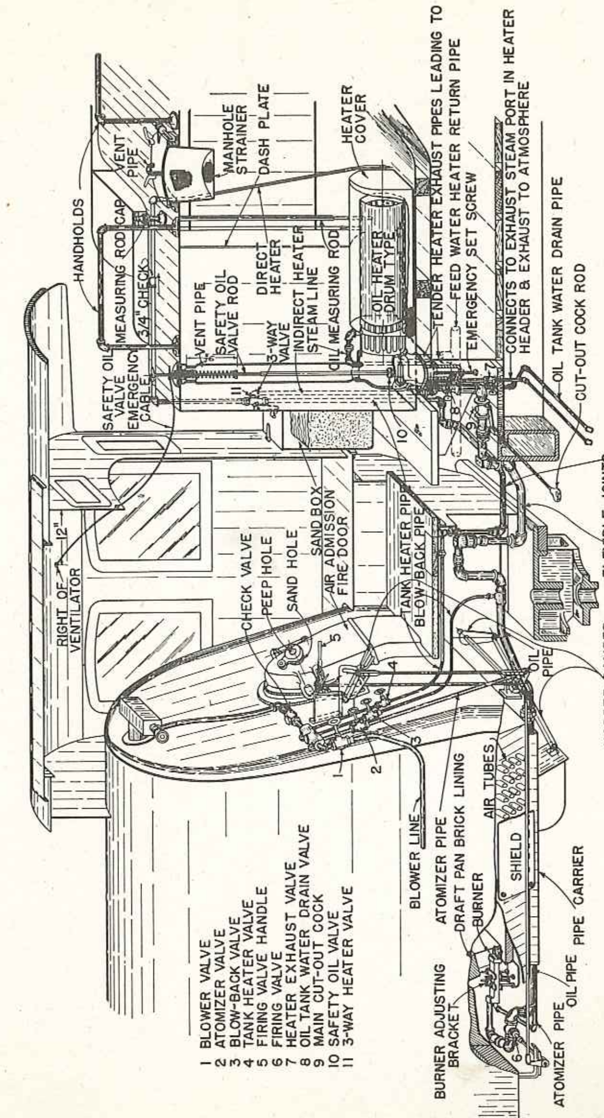
To Blow Out Burner. Be sure no one is near the fire pan, close and fasten fire door, open blower valve wide, close main cutout valve No. 9, open blow back valve No. 3 and then open firing valve No. 6.

To Blow Out Oil Line. Close firing valve No. 6, open blow back valve No. 3 and then open main cutout cock No. 9.

To Shut Off Fire. Close firing valve No. 6. In case of emergency close cutout valve No. 9 and safety oil valve No. 10.

To Close Safety Oil Valve. Pull safety valve emergency cable which releases safety oil valve rod by pulling out cotter key on top of tank, allowing the valve to close automatically.

Under no circumstances, other than the valve being disconnected, should any obstruction be placed under this valve or its connections to prevent its proper operation.



ARRANGEMENT OF EQUIPMENT ON AN OIL BURNING LOCOMOTIVE. FIG. 17.

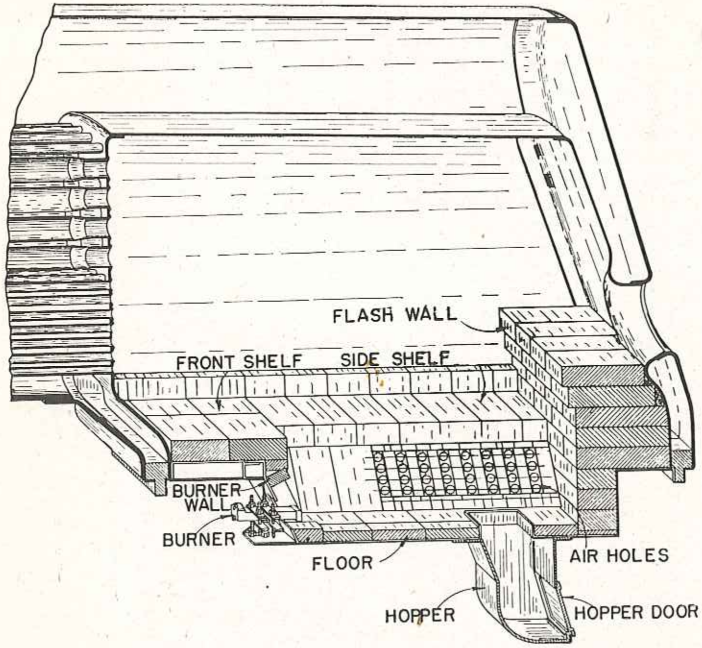


FIG. 18.

Fire Pan and Brick Work on an Oil-Burning Locomotive.

GENERAL INSTRUCTIONS

Leaks. Oil tank and pipe lines connecting oil tank to burner should be maintained free from leaks, and any leaks discovered shall be repaired at once.

Lost Motion Between Locomotive and Tender. Excessive lost motion between locomotive and tender should not be permitted to exist, as it will tend to loosen or break pipe connections, causing leaks.

Maintenance of Safety Oil Valve. The safety oil valve in the tank and the wire cable from the cab shall be maintained in an operative condition at all times.

Operation of Safety Oil Valve, and Cutout Valve. In case of fire in the cab or accident of any description the hostler, fire builder, engineer or fireman should pull the safety oil valve cable immediately and be positive that the safety oil valve is closed. Immediately thereafter, the cutout valve under the tender deck should be closed. The operating rod to the cutout valve is on the left side near the gang way step, and the valve is closed when the operating handle is pulled out. It is important that both the safety oil valve and cutout valve be closed.

Oil Tank Vent. Enginemen, hostlers and fire builders should see to it that the vent on top of the manhole in the fuel oil tank is open.

Atomizer and Damper. The same adjustment of atomizer and damper will not apply to all locomotives. A slight change will often produce better results.

Carbon Accumulation. The bottom of the draft pan, and the mouth of the burner should be inspected to see that carbon accumulation, brick or other foreign matter does not obstruct the oil spray from the burner. In case carbon is formed, which obstructs the oil spray, it should be removed.

Heating Fuel Oil. Observe level of oil in tank while heater is in operation, as heating of the oil might cause tank to overflow.

In case of accident, derailment, fires, etc. close oil safety valve by pulling cable to remove pin from rod, which will allow the rod to drop on seat, and close cutout valve under the tender deck. This will prevent oil running out, and lessen the danger of fire.

STARTING FIRE

In order to start a fire in an oil-burning locomotive, it is necessary to have steam for heating and atomizing the oil, as well as for creating draft through the draft pan and boiler. This steam is usually secured from the roundhouse blower lines or from another locomotive, and should be connected to the blower line of the locomotive to be fired up. Next open blower valve No. 1. Then use atomizer, heater and blow out valve the same as if the locomotive is working under its own steam. The oil-burning equipment and blower should be operated on steam from the roundhouse blower line until the steam pressure on the boiler is equal to the pressure on the blower line, after which they should be operated on steam from the locomotive boiler.

In starting the fire in an oil-burning locomotive having 20 pounds of steam pressure on the boiler, the oil-burning appliances may be operated entirely with the steam from the boiler and no connection with the roundhouse blower line is necessary.

The following precautions should be observed before starting a fire in oil-burning locomotives:

(a) See that the locomotive is securely blocked with chains provided for this purpose.

(b) Turn on the blower and open the dampers to allow any gas that may be present in the firebox to pass through the tubes and out of the smoke stack.

(c) See that the boiler is properly filled with water which can be determined by opening water glass cocks and gauge cocks to see that a continuous stream of water runs out of the open cocks. Neither the water glass nor the gauge cocks alone should be relied on to determine water level.

(d) Open the fire door and examine the interior of the firebox to see that the brick work is in serviceable condition, the draft pan has been properly cleaned since last trip and the floor of the pan is free from accumulation of carbon, loose bricks or other obstacles which will obstruct the atomizer jet in delivering oil from the burner to the combustion area.

(e) See that the steam and oil openings in the mouth of the burner are free from obstruction. The atomizer opening should be blown out by opening atomizer valve No. 2 at which time the steam should flow from the jet in a flat fan-like spray. If the spray is not uniform, the steam opening probably requires cleaning which should be done before the locomotive is fired up.

(f) Immediately before lighting the fire, see that no one is working under the locomotive near the firebox.

When everything is ready for lighting the fire, increase the blower strong enough to create the necessary draft. Next, open the atomizer valve and blow out any water that may have condensed in the burner and pipes, then close the valve and throw a bunch of burning waste on the floor of the pan in front of the burner. Old scrap cotton waste saturated with oil should serve this purpose. The burning waste should be placed not less than two feet from the mouth of the burner. **Close and fasten the fire door, leaving the sanding hole cover open so as to observe the fire.** Next, turn on the atomizer strong enough to carry oil from the burner to the burning waste, then open firing valve No. 6 slowly and cautiously until ignition of the oil takes place. After ignition of the oil has been established and the fire is burning steadily, the atomizer and firing valve should be opened wide enough to carry the flame back to the flash wall. When the fire is first started and the brick work is cold, only a light fire should be maintained, but later, as the brick work becomes heated, the fire may be increased as desired. It is necessary to see that all of the oil passing through the burner is being consumed in the

firebox and that none of it is dripping down into the pit or on the ground under the locomotive. An accumulation of oil under the firebox is liable to catch fire, consequently should be avoided.

The burning of oil in the firebox should be observed through the sanding hole and peep hole and under no condition should the fire door be opened while the fire is burning. A fire having a bright color denotes proper burning of oil, while a dull red, smoky flame indicates that the oil is not being consumed and is resulting in black smoke as well as soot accumulation in the firebox and tubes.

Fires in oil-burning locomotives standing in the roundhouse, on side tracks or at terminals, should be carefully watched to see that the fire does not unexpectedly go out. It is particularly important to give special attention to this feature when locomotives are being fired up, as the fire is more likely to go out when the brick work is cold than when the bricks are fully heated. In case a considerable quantity of oil collects under the firebox of a locomotive having a fire in it, the accumulation of oil should be promptly covered with sand, or the locomotive should be moved far enough away from the oil accumulation to eliminate danger of fire.

In relighting fires which have gone out or have been extinguished, a bunch of burning waste should be thrown into the firebox and the fire door fastened shut as has been previously described, before the firing valve is opened. **No attempt should be made to relight the fire from the heated brick work.** The practice of doing so is dangerous and is strictly forbidden, as it frequently causes explosions which damage the brick work and may result in personal injuries to other workmen on or near the locomotive.

If the fire is extinguished but a short time and the brick work is still hot or even warm, the blower should be used to clear the firebox tubes and smoke box of explosive vapors before any attempt is made to relight the fire.

In firing up when steam is not available, wood may be used until 20 pounds of steam is generated in the boiler (less than this pressure will not be sufficient to atomize the oil). The wood should be placed in the firebox with great care so as not to damage the brick work or burner. The wood used for this purpose should all be consumed before the locomotive is allowed to leave the terminal. Oil-burning locomotives which have been fired up with wood should be started carefully on leaving the terminal to prevent throwing of sparks from the smoke stack which might start fires along the right of way.

White or milk colored smoke at the stack of an oil-burning locomotive is an indication that the fire has gone out and the oil is flowing on the hot brick work in the fire pan. This white colored smoke is a highly explosive gas and before relighting the fire, the oil should be shut off and the firebox cleared of explosive gases before relighting the fire in the way previously outlined.

HANDLING LOCOMOTIVES AT TERMINALS

When oil-burning locomotives are standing with the fire lighted, the boot leg damper should be closed and blower shut off, unless it is necessary to use a light blower to keep gas out of the cab. Where conditions will permit, it is desirable that locomotives left standing under steam should have the fires turned out and all dampers closed, except at regular intervals when the hostler or watchman can be present long enough to fire the locomotive sufficiently to keep steam pressure and water in the boiler.

An oil-burning locomotive in which a low fire is burning, should not be moved under its own steam without first increasing the flow of oil to the burner by the amount necessary to prevent the strong draft created by the exhaust from extinguishing the fire. In opening the throttle, care should be taken not to slip the drivers, or produce a sudden strong exhaust. This is especially necessary when there is no one attending to the firing valve, as the sudden increasing of draft usually extinguishes the fire, unless proper precaution is taken.

A good strong fire should be maintained while working the injector on a locomotive standing under steam, and under no circumstance should an injector be opened when the fire is out.

When preparing locomotives for service, hostlers should see that the fuel oil is heated sufficiently for the road trip, and water accumulated in the oil tank is drained out.

Oil-burning locomotives arriving at terminals should be taken into the roundhouse, and have the fires extinguished as promptly as possible in order to save fuel, and avoid the severe strains on the boilers incident of holding locomotives under steam. Care should also be taken to avoid holding outgoing locomotives under steam longer than is absolutely necessary.

When extinguishing the fire for the purpose of killing the locomotive, or preparatory to leaving it stand for some time without the attention of a hostler or watchman, the safety oil valve No. 10, in the oil tank, should be closed first, and the firing valve left open long enough to allow the oil in the pipe line to be burned. After all of this oil has been consumed, the firing valve No. 6, cutout cock No. 9, and all dampers should be closed. It is important that these precautions be observed particularly when placing locomotives in the roundhouse as the firing valve may accidently be opened by workmen in the cab, and if the other valves have not been closed, oil will escape through the burner, thus creating a fire hazard and a waste of oil.

DUTIES BEFORE DEPARTURE

The requirements of the book on operating rules shall be complied with and in addition thereto, the fireman on an oil-burning locomotive should observe the condition of draft pan, brick work, burner, dampers and pipe connections between locomotive and tender. He should try the emergency oil valve, see that the burner is properly delivering fuel to the fire and that the heater

is working properly, also that proper supply of fuel oil, sand and water have been provided as well as the necessary tools for handling an oil fire.

The fireman must see to it that the cutout cock under the tender deck is in full open position so that a full flow of oil to the burner can be assured. This cutout cock is in open position when the operating handle is pushed in.

FIRING

The fireman should be at the firing valve when the locomotive is started. He should increase his fire immediately before the throttle is actually opened, and should reduce it immediately after the throttle is closed. Any change in the position of the throttle or reverse lever while running, should be correspondingly anticipated by the fireman, and the fire regulated accordingly. When switching, or on the road, the fire should at all times be regulated to suit the work the locomotive is performing. When the driving wheels slip the firing valve should be opened sufficiently to guard against the fire being extinguished by the excessive draft.

The engineer should call the fireman's attention when about to change the position of the throttle or reverse lever.

A white incandescent color at the peep hole in the fire door, and a slight haze of smoke at the stack are most desirable. Black smoke indicates incomplete combustion and waste of fuel, and should be avoided. An absolutely clear stack indicates an excess of air in the gases of combustion, which results in greater firebox heat losses and consequently is not as economical a condition as the proper amount of air, which is indicated by a slight haze of smoke at the smoke stack.

The firing valve, and not the injector or feed water pump should be used to control the steam pressure. The operation of the injector or water pump should be as nearly continuous as possible while the locomotive is working. Variation in the steam requirements of the boiler should be met by change in the adjustment of the injector water valve or water pump throttle as required to maintain a proper water level in the boiler. If, when the locomotive is working, the steam pressure approaches the popping point, and the injector is shut off, the injector should be started only if the boiler needs water. If no water is needed the fire should be reduced. If the injector is started, the firing valve should be opened slightly, if necessary to maintain working pressure. In no case should the fire be reduced and the injector started at the same time, in order to prevent popping.

The use of the injector when standing or drifting should be avoided as far as possible. When it is necessary to use the injector under these circumstances it should be used intermittently and a good fire should be maintained as long as the injector is in use.

When oil-burning locomotives are standing or drifting, the damper should be closed and a light fire maintained in order to have as nearly as possible a uniform firebox temperature, thus preventing injury to firebox and tubes. It should be remembered that the preservation of firebox and flues is as important as keeping up steam or making time. Rapid changes in temperatures of boilers causes expansion and contraction which will develop leaks. To this end engineers and firemen should co-operate to prevent cold air being drawn into the firebox.

The firing of an oil-burning locomotive does not require any great physical exertion, but it does demand that close attention be given at all times to produce economical results. Each change of the throttle or reverse lever position, along with changes in speed, require that a change be made in the position of the firing valve. These changes should be made at the proper time to avoid black smoke or damage to the boiler.

TOOLS

Oil-burning locomotives shall be provided with a sand scoop and a carbon bar.

USE OF BLOWERS

The purpose of the blower on a locomotive is to create draft through the boiler at times when the cylinder exhaust does not create sufficient draft. When the cylinder exhaust creates an equal or greater draft the blower should be shut off.

It is necessary to use enough blower to maintain steam pressure on the boiler while water is being put into the boiler at times when the locomotive is not working steam. It is necessary to use just enough blower to keep the gases out of the cab and to create the necessary draft in the firing up process. It should be used in maintaining and increasing steam pressure as is desired at times when the locomotive is not working steam. At all times when the blower is being used it is necessary that a bright uniform fire be kept burning in the firebox in order to prevent damage to the firebox and flues. In order to accomplish this the fuel must be supplied through the firing valve at a rate which the draft will consume. If this is not done cold air will be drawn into the firebox which will set up strains, causing leaks.

The constant use of the blower on yard locomotives and the setting of the oil valve in a position which will maintain steam pressure while locomotive is working is wasteful in fuel and damages the firebox; consequently, firing a locomotive in this manner while switching, is prohibited. The blower should be used lightly and the firing valve adjusted for each change in the work of the locomotive.

Often the conditions are such that the use of the blower does not require that it be wide open, and a careful intelligent fireman will always use it as sparingly as possible. The noise of a blower is annoying, and its use should be avoided if possible around passenger trains, passenger stations and office buildings. A blower improperly used is very wasteful of fuel and a fireman should endeavor to fire a locomotive so that its use will be reduced to a minimum. The operation of the blower often times

reflects the degree of efficiency and ability of the fireman on a locomotive.

A blower wide open uses steam at a rate that would supply a 40 H. P. engine and it is important to use as little steam through the blower as is necessary to secure complete combustion without damage to boiler due to cold air.

USE OF ATOMIZER

Best results are secured on oil-burning locomotives by using sufficient atomizer to carry the oil from the burner back to the flash wall so that proper combustion will be accomplished, and the back portion and back corners of the firebox filled with flame which is necessary for good steaming. Too strong an atomizer will frequently result in carbon deposits on the flash wall and produce a rapid succession of explosions, commonly known as drumming, and will damage the brick work. If the atomizer jet is not strong enough it may result in imperfect combustion resulting in smoke and carbon deposits on the floor of the fire pan. Proper adjustment of the atomizer lies between these two extremes, and requires close attention by the fireman to obtain the best results.

When an oil-burning locomotive is standing or drifting with a low fire, the use of too much atomizer will create a succession of light explosions causing puffs of smoke at the peep hole. This can readily be seen and is accompanied by a disagreeable gas in the cab. Under the same conditions incomplete combustion results when using too little atomizer because the oil is not carried far enough into the firebox and waste results in oil dripping from the mouth of the burner into the firepan. If the fire kicks or smokes it is an indication that the atomizer should be re-adjusted. If it fails to stop the trouble, the damper adjustment should be changed to make sure that the admission of excessive air into the firebox is not responsible for the trouble. If the admission of excessive air is not the cause, the temperature of the oil should be investigated to determine whether or not cold oil with irregular feeding is responsible for the condition. Another possible cause for this trouble is that there is water in the oil causing irregular fuel supply. Water may be removed by opening the tank drain valve No. 8.

After the throttle is closed and the firing valve has been cut down, it is necessary to reduce the steam at the atomizer a corresponding amount. A slight change in the adjustment of the atomizer while the locomotive is working sometimes produces good results even though the locomotive seems to be steaming well. The amount of atomizer necessary varies with the temperature as well as the characteristics of the oil and it is important, from a standpoint of good steaming and conservation of fuel, that as much atomizer as is necessary to produce good combustion be used at all times.

SANDING OF FLUES

Flues shall be cleaned of soot by floating sand in the opening provided in the fire door, while the locomotive is working hard, allowing the exhaust to draw the sand through the flues, thus dislodging soot from the firebox and flues and allowing it to pass out the smoke stack. It is better to use sand frequently and a small quantity at a time, than to use large amounts only a few times in the trip. Each time the sanding operation is performed it should be continued until evidence is shown that the flues are thoroughly cleaned. It is necessary that the flues be cleaned of soot as soon as possible after the locomotive leaves a terminal or on leaving a side track where the locomotive has been standing still for any length of time to aid in good steaming. The amount of sanding which is necessary depends to a great extent on whether or not good combustion is obtained. Flues should be sanded at an opportune time as near the final terminal as possible in order to leave them clean when locomotive enters the roundhouse. This saves fuel in preparing the locomotive for the next trip, also cleans the firebox and flues so that the boiler work can be done without delay.

The best results in removing soot from the boilers of oil-burning locomotives are obtained by leaving the dampers open and allowing the draft to carry sand through the fire door. There is an occasional locomotive that will take sand better with the damper closed, but shutting off the air incident to closing the damper in itself forms soot, and the practice is not recommended where it is possible to sand the flues with the damper open.

Sanding should be done when the locomotive is working with a high draft, however, flues should not be sanded when passing stations or other places where sand and soot discharged from the stack would be objectionable.

Sand delivered to oil-burning locomotives for sanding flues should be thoroughly cleaned and dried. Sand containing pebbles is objectionable as the pebbles will fall on the floor of the fire pan and obstruct the flame, and will also tend to stop up flues and make a heavy sand deposit in the front end of the locomotive.

USE OF OIL HEATERS

Fuel oil should be kept hot enough to flow freely at all times. If too high a temperature is maintained it is liable to cause the oil to boil and pour out of the vent pipe over the top of the tank. Oil heated too hot also interferes with the steady flow of oil to the burner. The proper temperature which fuel oil should be heated depends somewhat on the nature of the fuel oil. Thick, heavy oil must be kept hotter than thin, light oil. As a rule the oil should be heated to a temperature that it will reach the burner at 165 to 190 degrees Fahr. or more. This may be determined by having the oil at a temperature that the back of the hand may be held on the pipe leading to the burner for the time that it takes to count three.

After the oil is heated to the proper temperature, the direct heater should be used only for about 30 seconds at a time, to agitate the oil. This should be done at least once each hour while

the locomotive is on the road. Otherwise free carbon will settle to the bottom of the tank, bake on the heater coils and clog the oil feed lines.

The oil heater should be turned on in advance of firing up to heat the oil sufficiently to insure a steady flow to the burner by the time the fire is lighted.

When oil-burning locomotives or their tenders are held out of service during freezing weather the oil tank heater should be drained and the water thoroughly blown out with air to prevent damage to the coils from freezing.

Indirect heaters should be watched closely to detect leaky coils. Oil discharge with the exhaust steam from the heater or excessive accumulation of water in the oil tank, are evidences of a leaky heater. Leaks in heaters should be reported and the necessary repairs made.

ADMISSION OF AIR

The admission of too much air in the firebox is usually accompanied by a pulsating flame and in most locomotives it is necessary to regulate the air supply by partially closing the boot leg damper until the pulsating is stopped.

Oil-burning locomotives while drifting should have as little air opening through the fire pan as is possible to use and get good combustion. In some cases it is possible to entirely close the boot leg damper, as sufficient air will be supplied through the tubes in the side of the fire pan, and around the burner.

Air is admitted over the fire through the fire door. The air entering the firebox through the fire door is drawn through an air duct that extends below the locomotive cab deck. The admission of air through sanding hole is not permitted and the sanding hole cover should be kept in closed position except when sanding flues.

BLACK SMOKE

Black smoke at the stack of oil-burning locomotives is a waste of fuel and must be avoided. This is evidence of imperfect combustion, and in most cases is due to conditions which the firemen can control by proper handling of the firing valve, atomizer, heater and dampers. If it is found impossible to make a locomotive steam without smoke, the cause of the trouble should be ascertained and reported on arrival at the terminal in order that the necessary repairs may be made.

Black smoke at the stack results in the heating surfaces of the boiler being covered with soot which is a non-conductor of heat and may cause an oil-burning locomotive to fail for steam.

Particular care and attention is required to prevent black smoke when starting and stopping the locomotive. This can be accomplished by proper cooperation between the engineer and fireman in handling the throttle and firing valves.

EXTINGUISHING OIL FIRES

All roundhouses in which oil-burning locomotives are handled shall be provided with strong barrels of about 50 gallons capacity for storing sand to be used in extinguishing oil fires. One barrel is to be located between every alternating pair of pits. These barrels shall be kept filled with sand and shall be inspected periodically to see that they are full of sand and that the sand is dry. The sand is not to be used for any other purpose than extinguishing oil fires. An old or scrap scoop shall be kept on top of each barrel.

The barrels shall be painted red and stencilled with black letters 2" high as follows: "SAND FOR OIL FIRE ONLY." Similar fire extinguishing equipment shall be maintained at inspection pits and oil supply stand pipes.

In case of oil which has dripped into the pit or elsewhere catching fire, sand should be thrown on it promptly. Sand will put out an oil fire where water will not.

If oil is escaping from the fire pan or broken or leaky pipes under the locomotive or tender, the safety oil valve, which is valve No. 10 in the tender oil tank, should be closed by pulling the emergency cable and close cutout valve No. 9. If access to either of these valves is prevented by fire, the cutout valve No. 9 can be closed at a safe distance by means of a clinker hook or carbon hook applied to the loop in the handle of the operating rod controlling the cutout valve. The end of this operating rod will be found near the gangway steps on the left side of the tender. Cutout valve is closed when the operating handle is pulled out.

MEASURING OIL

To determine the amount of oil in the tank, lift the measuring rod and wipe off the oil. Then lower the rod into the tank slowly and leave it there for several seconds before taking it out to read the number of gallons registered. Before taking measurements, be sure that the oil has stopped splashing around in the tank, as a correct measurement cannot be taken until the oil has reached a constant level. When wiping the rod see that threads of waste do not adhere to it, as they will finally reach the valves and oil lines and might possibly clog them up. Do not drop waste on top of the tank, or allow it to collect on the tank under any circumstance.

Accurate measurements of oil cannot be secured when the locomotive is in motion, or when the direct heater or indirect heater is turned on. It is important that care be exercised in the measuring of oil by hostlers, fuel station attendants and engine crews. Fuel oil tickets covering issues of fuel oil to locomotives shall be made out to show the correct information required on this form, and this shall be done by the engine crew if there is no fuel attendant on duty. After measuring oil replace cap over measuring rod.

EFFECT OF WATER IN FUEL OIL

Water in the fuel oil will cause the flame to burn with intermittent flashes or kicking of the fire, and will at times die down

entirely and flash up as the water disappears and the oil reaches the burner. This condition will result in the steam pressure dropping very rapidly and may cause the flues to leak. It is a dangerous condition and may be relieved by opening the tank drain valve No. 8 and draining the water from the fuel oil tank, however, most of the fuel oil is too heavy for the water to separate from the oil and the direct heater should be used to thoroughly mix the oil and water, and thus avoid a quantity of water flowing to the burner intermittently. Any continued use of the direct heater should be avoided as this will increase the amount of water in the oil.

INSPECTION AND MAINTENANCE

An oil burning locomotive arriving at a terminal should have all parts of the oil-burning equipment carefully inspected, and if repairs are needed they should be made promptly. The burner should be examined to make sure that it is in good working order, and in proper position and alignment. All piping, valves, flexible joints, etc., should be examined for leaks, loose clamps, etc. The fire pan and its support should be carefully examined to see that they are in good condition and that no part of them comes in contact with the frame, spring rigging or machinery. The fire pan should also be inspected for air leaks, particularly around the mud ring. The damper should be examined and tried to see that they work properly. As soon as the locomotive has cooled off sufficiently, the inspector should enter the firebox and examine the brick work to make sure that it is in suitable condition for service and that there is no likelihood of bricks working out of place or falling down into the bottom of the pan. Accumulation of carbon, sand and other foreign matter should be removed from the fire pan after each trip. In case of excessive deposit of carbon, the cause of the trouble should be ascertained and proper remedy applied. The fire pan and burners shall be cleaned out after the other operations have been performed and all of this work should be passed on by a competent boiler inspector or other authorized person before the locomotive is fired up.

FILLING FUEL OIL TANKS

Do not carry, or permit anyone to carry oil lamps or oil torches within a distance of 10 feet of any oil tank manhole while open.

Incandescent lamps or pocket flashlights only, should be used around oil tank manholes when taking oil. Avoid turning electric lights on or off near the open manhole which might produce a spark to set off an oil vapor.

Before taking oil see that the screen or strainer is properly in place in the manhole. A tender oil tank should not be filled to more than within two inches of the top, as oil expands considerably when heated, and may overflow.

When taking oil and after the valves of the spout have been closed, allow the spout to drain before removing it from the manhole. Spouts provided with drip pans or receptacles to prevent loss of oil shall have same properly applied before the spout is moved away from the manhole. Careful attention to these matters is necessary in order to prevent waste of oil and to prevent oil being spilled on the top of tanks where engine men, train men and others may slip and fall while walking over the top of the tank.

After the tank has been filled, clamps which hold the manhole cover shall be put in place, tightened and kept tight until it is necessary to take another supply of fuel oil. Manholes should be kept closed except when the tank is being filled with oil.

If oil is spilled or boiled over the top of the tank, the engineer should make a report on arrival at terminal to have oil cleaned off.

ENTERING FUEL OIL TANKS

Before fuel oil tanks are entered by workmen the tank **must** be steamed out thoroughly and then washed out with cold water to insure the removal from the tank of any gas that may have accumulated. Employes are positively prohibited from entering fuel oil tanks which have contained fuel oil until the above instructions have been complied with, and they shall keep lanterns, torches, or any other open lights out of the fuel oil tanks. When necessary to have artificial light in an oil tank, use only electric or flash lights.

BOOTH BURNERS

Burners when finished complete shall conform in all dimensions to blueprint drawings No. 176-214 for the 3½" burner, 176-60 for the 2½" burner, 176-51 for the 2" burner and 176-87 for the 1½" burner.

The oil port and atomizer slot should be in proper relation horizontally to each other so that an even distribution of oil will result. Low corners are to be considered defective.

Atomizer steam slot should extend ⅛" beyond the oil port opening and should have a smooth orifice measuring exactly $\frac{1}{32}$".

An oil-burning locomotive undergoing general repairs should have the oil burner removed, cleaned, repaired and inspected. Defective burners should be removed and replaced with new or reconditioned burners, and the defective burners sent to Topeka, Cleburne, Albuquerque or San Bernardino shops for repairs. Burners to be repaired should be thoroughly cleaned in a lye vat.

New and reconditioned burners shall be properly inspected and tested before placed in stock or on a locomotive for service.

Burners should be placed on a steam line in a horizontal position and condition of atomizer steam jet noted. The jet should spread equally up and down from the horizontal plane through the burner. If the spread is either up or down in an unequal proportion the burner should be rejected and reworked.

Any burner shall be rejected if steam leaks into the oil cavity while under test.

New burner castings shall be given a surface inspection for cracks and sand holes or spongy condition which will cause a leak in the oil cavity. Castings appearing defective shall be tested by connecting to a steam line and passing steam through the oil cavity. If leaks are found the burner should be scrapped.

The atomizer slot of each burner shall be gauged with taper gauge to insure correct size of opening which is $\frac{1}{32}$ in.

All burners sent to Store Department stock should have the inspector's stamp to indicate inspection and acceptance.

The burners should be applied so that the atomizer jet will be parallel to the floor of the fire pan and approximately central between the sides of the pan. Page 63 of the Locomotive Folio shows the method to be followed in lining up oil burners in locomotives.

APPLYING BRICK WORK

Brick work in oil-burning locomotives shall be applied and maintained in accordance with the brick work folio.

In applying brick work the spaces between bricks are to be filled with a mixture of fire clay and water thoroughly mixed to a consistency of thin paste. The bricks shall be placed as close together as possible and where special shapes of brick are not provided, the lining shall be built up using small pieces of brick laid in fire clay. Large quantities of the fire clay mixture should not be used at one point or be depended upon entirely as a fire resisting surface.

Under no circumstances shall brick work be cooled by pouring water over the surface.

HOLLOW STAYBOLTS

Staybolts behind all brick work shall be hollow. As locomotives in coal-burning service are changed to oil-burning service, hollow staybolts shall be applied back of the brick work as the oil-burning equipment is applied.

The hollow staybolts shall have a $\frac{3}{16}$" hole through the whole length, the hole being located centrally. The outside ends of hollow staybolts shall not be covered with lagging.

GENERAL

Safety Oil Valve. The safety oil valve on the tank and the wire cable to the cab must be kept in good order and be operative at all times.

Fire. In case of accidental fire when standing, or in case of derailment or accident when running—the hostler, fire-builder, engineer or fireman, or whoever is on engine, must pull the safety cord immediately and be positive that the safety valve is closed, then close cutout valve under tender deck.

Carbon bar. Hot carbon bars must not be placed on top of oil tank as it may result in a serious fire or explosion by igniting oil vapors escaping from oil tank vent pipe.

Fireman. The fireman should not wait for the engineer to instruct him to shut off the oil supply. It is his duty to watch and to be governed by the engineer's movements of the reverse lever and throttle.

Blower. The blower should be used with judgment. Open it sufficient to create the necessary draft when the throttle is closed. Too much opening is hard on the flues and sheets.

Brick Work. Examine the brick work at the end of every trip.

Firing. Care should be taken to maintain an even temperature in the firebox. It should not be increased too rapidly by forcing the fire or reduced suddenly by permitting cold air to pass through the firebox and flues. It is of the utmost importance that this even temperature be maintained to preserve the life of the firebox and flues, and to prevent locomotive failures by leakage of same.

Wasting Fuel. In view of the ease with which an extravagant waste of fuel can be effected in burning oil, it is especially urged that every effort be exerted to properly handle the locomotive and the burner and its accessories, in order to obtain economical combustion and to guard against injury to the boiler or firebox.

STEAM

The so-called vapor seen escaping from a vessel of boiling water, or rolling in clouds from the exhaust of a locomotive is composed of very minute drops of water. It is one of the physical manifestations of steam resolving itself back to water through the process of condensation. The change which is visible is caused by the contact of the steam with cold air.

As the water in a boiler is transformed into steam it rises into the steam dome and from there it is released by opening the throttle valve and is then conveyed through the dry pipe, superheater and steam pipes to the steam chests and from there to the cylinders. The expansive power of the steam exerted on the pistons in the cylinders is the basis of the propelling power of the locomotive.

Saturated steam is steam either in contact with the water from which it was generated, or if separated therefrom is kept at the same temperature and pressure. Wet steam is steam not only saturated but also holding in suspense unevaporated water in the form of minute drops; it holds this water in suspense mechanically, due either to such causes as ebulition or rapid boiling of the water from which it is generated, or from a rapid flow of steam from near the surface of the water, or from partial condensation.

Dry steam is the term usually used for saturated steam that is free from suspended water. It is used in distinction from wet steam. Superheated steam is steam removed from contact with water, and heated above the temperature of the water from which it was generated. Steam more closely resembles a perfect gas when superheated than in any other state.

EXHAUST NOZZLE AND DRAFT

The steam, after it has been admitted to the cylinders is used for another useful purpose. After it has performed its work in the cylinders of the locomotive it is exhausted through the nozzle tip and smoke stack to create the necessary draft for the proper combustion of the fuel placed in the firebox.

The nozzle tip is so constructed that the steam passes out much in the same manner as a stream of water through a hose nozzle, the column of steam being allowed to expand sufficiently so that it touches the inside edges of the smoke stack on it way out. If it is desired to increase the velocity of the steam passing through the nozzle tip, it is necessary to increase the pressure forcing it through the tip. Usually this is done by reducing the size of the opening so that the desired increase in pressure will be obtained. In this manner air is driven out of the smoke stack which causes air in the smoke box to also be drawn out with the steam. This creates a circulation of air through the flues and firebox, and when the fire door is closed, circulation is also established through the grates and ash pan. The steam generated in the boiler, therefore, is used not only to propel the locomotive, but also to provide the draft necessary for the proper burning of the fuel placed in the firebox.

It is obvious that under like conditions of pressure, etc., a large opening will permit a given volume of steam to escape in a shorter time than will a smaller opening, therefore, the nozzle tip should be as large as possible and still impart to the exhaust jet sufficient velocity to properly drive the gases out of the smoke stack and flues, producing the necessary circulation through the flues and fire box for proper steaming. Reducing the nozzle opening restricts the flow of steam from the cylinders to the atmosphere in proportion, and if reduced sufficiently the results will be practically the same as when the locomotive is improperly handled by working the valves at long cut-offs under high speeds.

In order that there might be a free flow of air through the ash pan, grates, flues and smoke box, the nozzle tip must be maintained in its proper relation to the smoke stack. On account of the nozzle tip being located so far below base of smoke stack, it is necessary to provide means of directing the exhaust into the stack to prevent its spreading out and a part of it striking outside the base of stack and being driven back into front end. This was accomplished in the earlier locomotives by placing a pipe known as a petticoat pipe above the nozzle, which permitted the use of a larger nozzle tip.

On later types of power the petticoat pipe is replaced by what may be considered an extension of the smoke stack into which the steam from the nozzle expands and is directed up through the stack.

LAYDEN EXHAUST NOZZLE

With nozzles which have a single opening through tip, there is a period during the exhaust when a portion of the steam, which is being exhausted from the cylinder on one side of locomotive is forced over into and produces back pressure in the cylinder on the opposite side which results in considerable loss of power.

The Layden exhaust pipe and nozzle for locomotives is so designed that there is no possibility for the exhaust steam from one cylinder to cross over and create back pressure in the opposite cylinder. The elimination of this back pressure increases the maximum turning effort transmitted to the crank pin, during that part of the revolution when one crank pin is near either the top or bottom quarter and one cylinder is doing all the work. This increase in effective power is more pronounced at low speeds when the highest tractive effort obtainable is necessary.

This exhaust pipe divides the exhaust steam from either cylinder so that it is emitted through two openings in such a way as to fill the stack properly which produces a greater vacuum per pound of back pressure and allows a larger total opening of the exhaust passage, further reducing back pressure in the cylinders.

The construction of the exhaust pipe and nozzle is shown in the photograph in Fig. 19 and by the diagrammatic sketch Fig. 20. In the ordinary single nozzle the exhaust steam from both cylinders use a common channel of escape and the steam released from a cylinder pressure of 150 pounds or more not being vented immediately crosses over into the empty end of the other cylinder and creates a momentary back pressure against the piston for approximately twenty-five per cent of its travel at mid stroke. This is shown diagrammatically in Fig. 20.

The diagrammatic sketch Fig. 20 would indicate that the Layden exhaust pipe has only two exhaust nozzles. This is merely to show how the exhaust from either cylinder is kept separate from the other. In reality each of the exhausts are separated into two jets, as mentioned above, arranged in line with the center of stack, one set longitudinal with the boiler and the other transverse which balances the draft in the stack instead of having a heavier blast on one side than the other as would be the case if only one nozzle opening for each cylinder were used.

FIG. 19.

Layden Exhaust Nozzle.

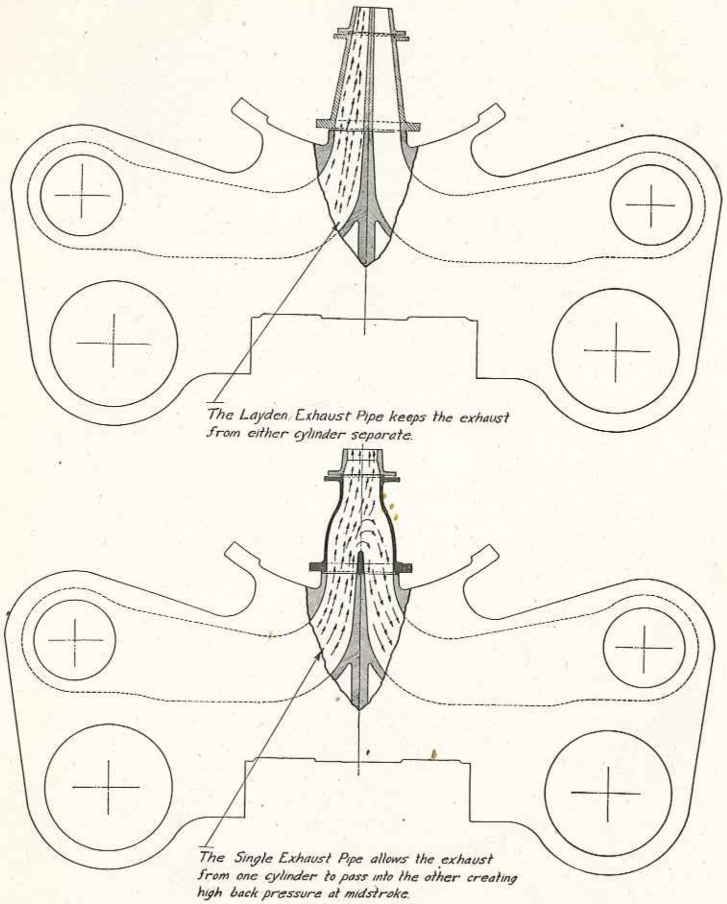


FIG. 20.
Exhaust Pipe Arrangements

ACTION OF STEAM

In steam, as in other gases, there is a natural repulsion between the various particles, each particle trying to separate itself from the others so that it will fill the receptacle in which it is confined. Its natural tendency is to expand and thus push out whatever is resisting it. If the steam is enclosed and superheated, the natural tendency of its particles to separate is intensified and thus obtain increased work from a given weight than is possible with saturated steam.

When the exhausts at the smoke stack of a locomotive are loud and heavy, steam under a heavy pressure is being passed through the nozzle tip. Steam under a heavy pressure has power to do considerable work, and unless it is permitted to escape from the cylinder after it has done its work, it will resist the return movement of the piston by offering what might be termed back pressure, or a pressure in the cylinder on the exhaust side of the piston, which prevents the live steam on the opposite side from freely moving the piston throughout its stroke.

When the exhausts from the nozzle are sharp and there is an interval between the exhausts when no sound is produced, it is evident that the pressure in the exhaust side of the cylinder is very low. On the other hand, if the steam is being discharged at the nozzle tip so rapidly and in such quantities that the exhausts are very loud and there is no interval which will enable the exhausts to be readily distinguished, the steam which is being exhausted is still capable of doing considerably more work through its expansive power and also there remains in the cylinder a considerable pressure which is tending to obstruct the return movement of the piston. Such a condition is brought about by so working the locomotive that the steam from the boiler is allowed to follow the piston almost its entire stroke, until the speed has been increased to such an extent that the flow of steam through the exhaust channels in the saddles to the nozzle tip is practically continuous. Under these conditions the live steam from the boiler is retarded in its work of moving the piston by the pressure thus maintained on the exhaust side of the piston. This reduces the power that it is possible for the locomotive to develop and the speed that it might attain.

Shortening the cut-off, by moving the reverse lever toward the center allows the boiler pressure to follow the piston through only a portion of its stroke and permits the steam to complete the piston's movement under its expansive power, at the same time causing its pressure to be reduced by the time the valve opens the exhaust port, when a further reduction in pressure takes place. The results then would be the same as carrying an increased boiler pressure, because the pressure on the exhaust side of the piston would be considerably reduced, giving more power to the live steam on the opposite side of the piston, permitting it to force the piston more freely throughout its stroke. It would be possible to distinguish each exhaust as it occurred, by providing an interval during which there was little or no pressure remaining in the cylinder, and it would be possible to obtain greater power and speed with the same amount of steam or maintain the same power and speed with a greatly reduced expenditure of fuel and water.

The natural tendency is for steam under pressure to expand or push out in all directions. If, therefore, steam is admitted to a locomotive cylinder at 100 pounds pressure and is caused to follow the piston at this pressure for its full stroke, the average cylinder pressure would be 100 pounds.

If steam at 150 pounds pressure is admitted to the cylinder and allowed to follow the piston at this pressure for only a short distance, and is then cut off by the valve closing the steam port, the confined steam in the cylinder will continue to push on the piston after the supply from the boiler is cut off. In this case the withdrawal of steam from the boiler only lasts until the valve closes the admission port, after which the steam begins to expand.

If the steam, which was admitted at 150 pounds pressure for only a portion of the stroke, had reduced to 50 pounds pressure when the valve opened the exhaust port after the steam had completed the movement of the piston, then the average pressure would be 100 pounds as in the former case. A smaller volume of steam at a higher pressure would have therefore given the same average cylinder pressure, and the pressure being lower when the exhaust took place would insure a lower pressure on the exhaust side of the piston during its return stroke.

AN EXAMPLE OF SHORT CUT-OFF VERSUS LONG CUT-OFF

As an example demonstrating the economy to be derived in working a locomotive with a short cut-off and full throttle, tests have shown that with a Mikado type locomotive handling a full tonnage train at 20 M. P. H. developing 1,775 horse power with the throttle partially opened and reverse lever set to cut steam off to cylinder when piston had traveled ⅔ of its stroke, used 6,482 gallons of water and 9,310 pounds of coal per hour.

The same locomotive, handling the same train at the same speed developing the same horse power but with full throttle and the reverse lever hooked up to cut steam off to cylinder, when piston had traveled ⅓ of its stroke, consumed 4,813 gallons of water and 6, 685 pounds of coal per hour.

These two cases reflect a saving of over 1¼ tons of coal per hour in favor of the shorter cut-off and heavier throttle, and while the comparison was made by using an extreme condition of locomotive operation, it serves to show what may be accomplished, in the saving of fuel by working a locomotive with the shortest cut-off possible to do the work and the throttle wide open if necessary.

It should be borne in mind that one of the sources of a great amount of fuel waste is in connection with the handling of trains where the time of such trains is easily made, in other words,

when the locomotive is being worked very much below its full capacity.

This is particularly true on passenger trains where, over portions of the road, the capacity of the locomotive is such that it must be worked very lightly. Under these conditions, the engineman should keep in mind that even though the power must be reduced, the reverse lever should be hooked up as far as practicable and the power reduced by easing off on the throttle, for a great amount of steam may be wasted without his realizing it, by having the reverse lever even one or two notches lower than necessary.

CONDENSATION OF STEAM

When steam comes into contact with surfaces of a temperature lower than the temperature of the steam, condensation takes place. If, therefore, a locomotive has been standing for a considerable period the various pipes and channels throughout the cylinder saddles, also the steam chests and cylinders may be at the normal temperature of the atmosphere or near that temperature, so that when steam is passed from the boiler to the steam chests some of the steam is condensed when it first enters these parts. A certain amount of condensation continues to take place until the cylinder saddles, steam chests and cylinders are heated up close to the temperature of the steam passing through them. It takes some little time to bring this about, that is, a locomotive will have to be operated for some considerable distance before all the parts which the steam comes into contact with have been heated up to as near the steam temperature as possible.

Dry steam under pressure is flexible, that is, if permitted to do so it will expand and fill a much larger space than that in which it is confined. In doing this the steam pressure will diminish as expansion takes place. Steam may also be compressed into a smaller space which will cause the pressure to rise.

When a reduction of pressure occurs, as stated above, the temperature of the steam falls at the same time, and if steam is allowed to expand until there is no pressure remaining, the temperature of the steam will be reduced to the point at which water boils in an open vessel, or 212 degrees F. The steam at this time would revert to water. On the other hand, if steam heavily saturated with water was compressed into a smaller space, the steam not being as flexible as when dry, could not be compressed to the same degree. Water itself is practically inelastic, therefore, when compressed its pressure rises very rapidly. If the piston was nearing the end of its stroke and the space between the piston and cylinder head was filled with water, a very slight movement of the piston would increase the water pressure enormously.

In order to provide for the removal of any accumulation of water in locomotive cylinders, holes are drilled in the bottom of the cylinder at each end, into which cylinder cocks are applied and so arranged that they may be opened or closed by the engineer from the cab. It is important therefore, that when there is a possibility of water entering the cylinder, that the cylinder cocks shall be opened and left open until the temperature of the cylinders and other parts connected thereto is such that the condensation of steam is reduced sufficiently so that the amount of water condensed will not be in such quantities as to completely fill the clearance space in the cylinder.

DAMAGE DUE TO CONDENSATION

The cylinder and all its parts, as well as all connections leading thereto are designed to withstand considerably more than the steam pressure ordinarily carried in the boiler. However, if water accumulates in the cylinder and is not allowed to escape through the cylinder cocks it must be forced out through the steam ports with the exhaust. If, when the piston is forcing water ahead of it out through the exhaust port, the valve should close as the piston nears the end of its stroke, there would be no further means of escape for the water remaining in the cylinder. The crank pin at this time may be pushing upon the piston after the steam pressure has forced the piston the greater part of its stroke, the crank pin at this time would be near the center and the momentum of the locomotive would tend to carry the crank pin by the center. Under these conditions enormous pressure would be created between the piston and cylinder head and also throughout the port leading to the valve chamber or steam chest. Heavy stresses would also be set up in the piston rod, the cross head and wrist pin, also the main rod and the main crank pin, in addition to the strains set up in the wheel, axle, driving box and frames.

The result of these strains is conducive to broken axles, driving wheel spokes, crank pins, bent or broken main rods, wrist pins, cross heads as well as loose guides, bent or broken piston rods, broken piston heads, cylinder and piston rod packing, cracked cylinder heads, or broken cylinder castings and broken main frames. This pressure is all out of proportion to that which can be obtained through the ordinary working of the locomotive under its full power, and since condensation is greatest when the cylinders, steam chests, saddles and their connections are cold, such as would be the case if the locomotive had stood for a considerable time, it is very essential that before starting a locomotive from a state of rest, cylinder cocks and channel cocks must be opened to allow condensation to escape from cylinders and valve chambers.

The cylinder cocks should be open while the locomotive is standing, in order that any condensation taking place in the cylinder will not accumulate.

The cylinder cocks must be opened before opening the throttle to admit steam to the cylinders when starting a locomotive from a state of rest. If the locomotive has stood for some time, allow sufficient time for the water to be blown from the cylinders after opening the throttle and until the steam showing at the cylinder cocks is comparatively free from water. The locomotive should

then be moved slowly for a few revolutions and no attempt should be made to hurry the movement of the locomotive, because under these conditions slipping of the drivers is liable to occur, in which case the piston speed may be so high that water in the cylinders is unable to escape through the cylinder cocks, or exhaust passages, and a sufficient amount will be trapped in the end of the cylinder when the valve closes the port to entirely fill the clearance space, causing a very heavy pressure in the cylinder. Under these conditions very damaging strains are produced and cylinder castings and other parts may sustain invisible cracks and later on fail in ordinary service.

Even after the locomotive has been moved out of the roundhouse to the outgoing track, the engineer should remember that the cylinders and their connections are still cold enough to produce considerable condensation, he should therefore move the locomotive slowly with cylinder cocks open when starting, and above all avoid slipping the locomotive at that time.

Cylinder cocks should also be opened whenever locomotive starts foaming bad.

VALVE GEAR

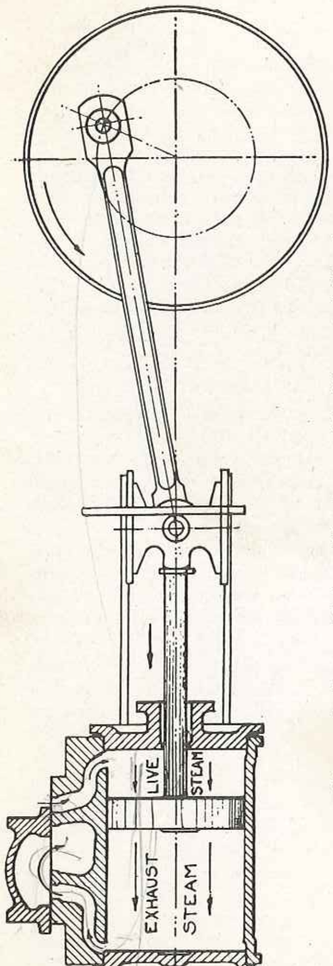
The term valve gear or valve motion refers to a system of eccentrics, eccentric rods and levers that transmit motion to the main valve which admits steam to, and exhausts it from, the cylinders of a locomotive. The principal parts are the eccentrics, the eccentric rods, the reversing link, the rocker arms and valve rods, the link hangers, reverse shaft arms, reversing shaft, reach rod and reverse lever.

The simplest forms of valve gear are shown in Figs. 22 and 23. Fig. 22 shows the location of eccentric relative to the main crank pin when but one eccentric is used and when the motion is transmitted directly to the valve. This form of valve gear is known as "direct motion."

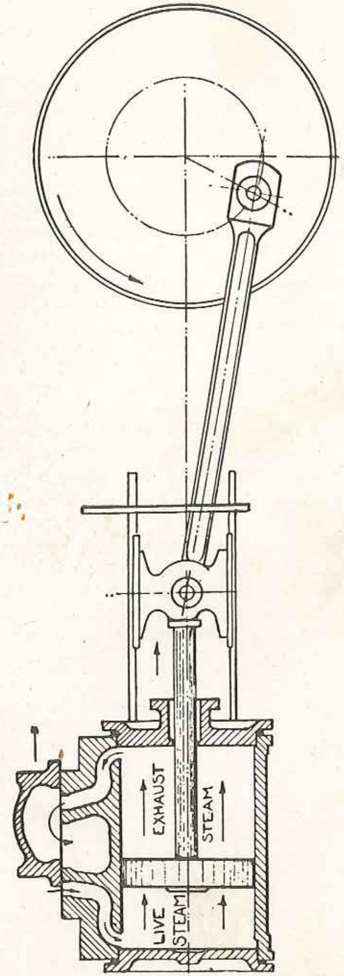
Fig. 23 shows the location of eccentric relative to the crank pin when the motion of eccentric is transmitted to the valve through a rocker arm and this form of valve gear is known as "indirect motion." In these illustrations the eccentric is set 90 degrees or at right angles to the crank pin.

The valves shown in these cuts, it will be observed are the same width as the distance between the outer edges of the steam admission port to the cylinder and the inside edges of the valve (exhaust edges) are in line with the inside edges (exhaust edges) of the steam admission ports. Valves so constructed are known as "line and line" valves.

The crank pin in either of these cuts is shown on forward center. This means that the piston is also at forward end of cylinder and that it will be necessary to admit steam to that end when the valve moves. With the crank pin on dead center there would be no movement, even though the valve was open to admit steam for the reason that the power delivered would be in direct line with center of axle, so that before the power will be effective,



Steam Action: Piston Moving on Its Forward Stroke.



Steam Action: Piston Moving on Its Backward Stroke.

FIG. 21.

it is necessary to move the crank pin off center. When this is done, and in the direction indicated by the arrow, the eccentric will move the valve to open the admission port to forward end of cylinder, which will allow live steam from boiler to flow against piston, forcing it backward causing the wheel to rotate.

At the same time that the valve opens the steam port to forward end of cylinder, the cavity in the under side of valve opens and makes communication from the steam port leading to back end of cylinder with the exhaust cavity in the valve seat which will allow steam from the back end of cylinder to flow to the atmosphere.

The valve will continue to open the ports (admission and exhaust) wider until the crank pin reaches the bottom quarter, when it will reverse its movement and start closing, and will have entirely closed both admission and exhaust ports when the crank pin reaches the back center, and as it passes back center the valve will have moved to open the forward end of cylinder to the exhaust and will be admitting live steam to back end of cylinder. Fig. 21 shows the action of the steam flowing to and from the cylinder in both directions of the piston. The student should study these diagrams until it becomes clear how the action of the eccentric moves the valve in relation to the crank pin and piston.

With a valve similar to those shown in Figs. 22 and 23 (line and line) live steam from the boiler must follow the piston its entire stroke and no advantage can be taken of the expansive force which it contains. In order to do this however, valves are so constructed that their outer edges overlap the outside edges of the steam ports, in other words the valve is made wider than the distance between the extreme edges of the steam ports leading to the cylinder. The amount that a valve over reaches the steam ports, when located centrally on its seat, is known as "outside lap" or "steam lap." If a valve so constructed was placed on an engine on which the eccentric was set at 90 degrees from the crank pin, the port would be closed, the amount the valve over lapped the outside edge of the steam port, when the crank pin passed center. This it can be seen, would not be desirable, so, in order that the port will be opened at the proper time, the eccentric must be advanced on the axle, in the direction the axle will be moved when controlled by the eccentric, a sufficient distance to bring the valve to a position to begin opening the port when the crank pin is on center. With a valve thus constructed, in order that it will be in position to open the admission port, at either end of cylinder, at the proper time, the admission port at opposite end, is closed, considerably in advance of the piston reaching the end of its travel, and after the valve so closes the admission port, the steam which is in the cylinder expands and exerts power on the piston the remainder of its stroke, without using live steam from the boiler.

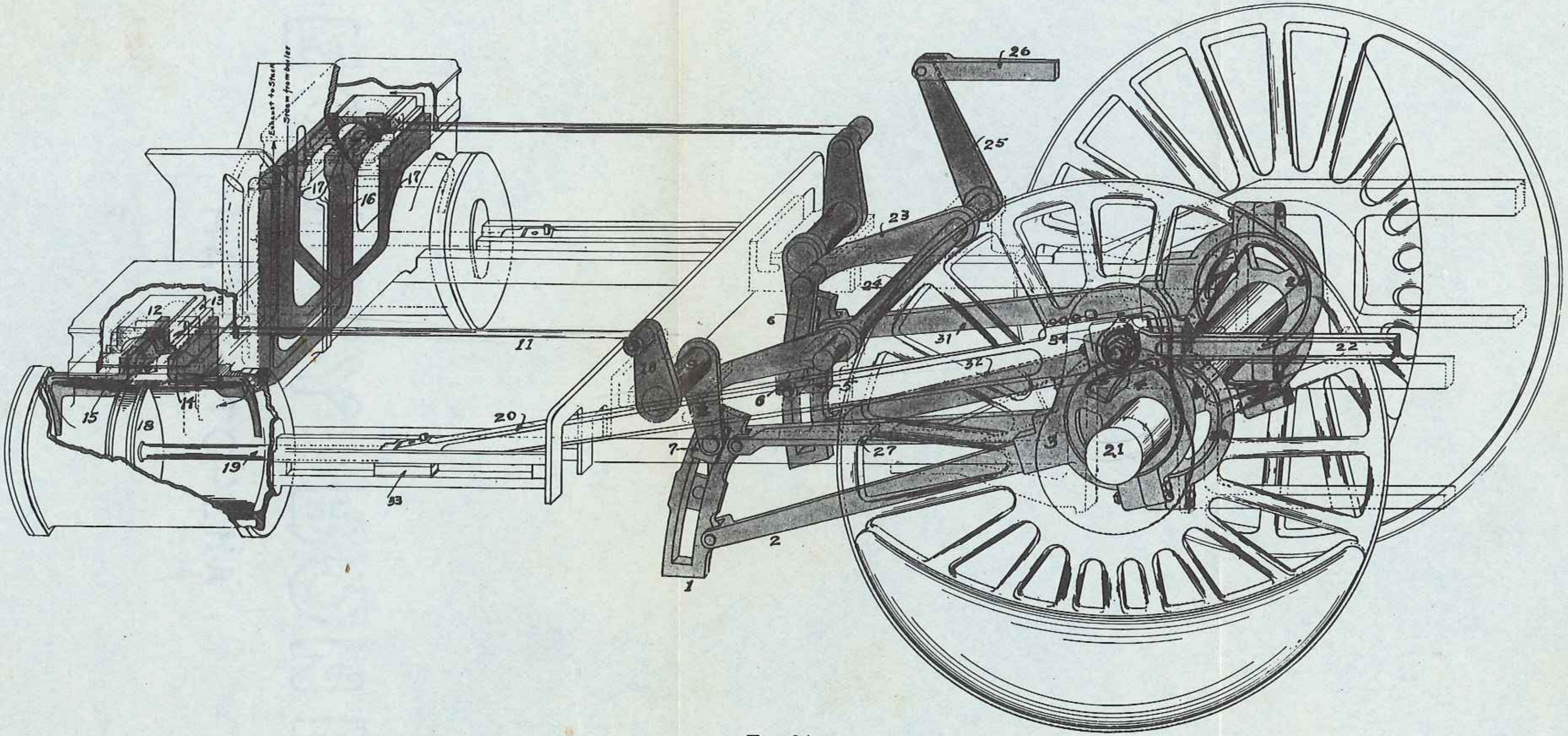


FIG. 24.
Stephenson Valve Gear Arrangement.

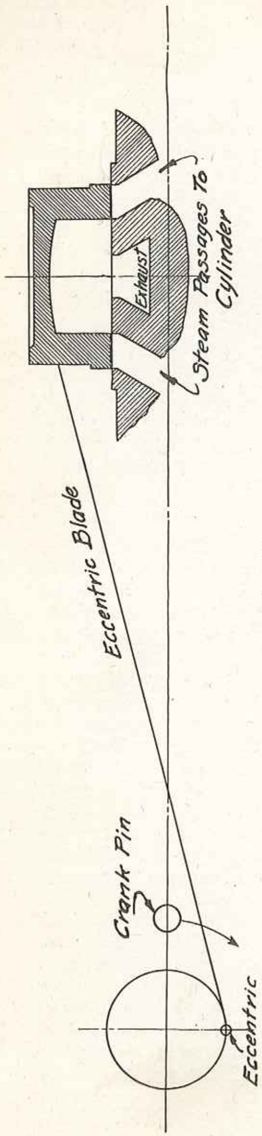


FIG. 22.
Direct Valve Motion.

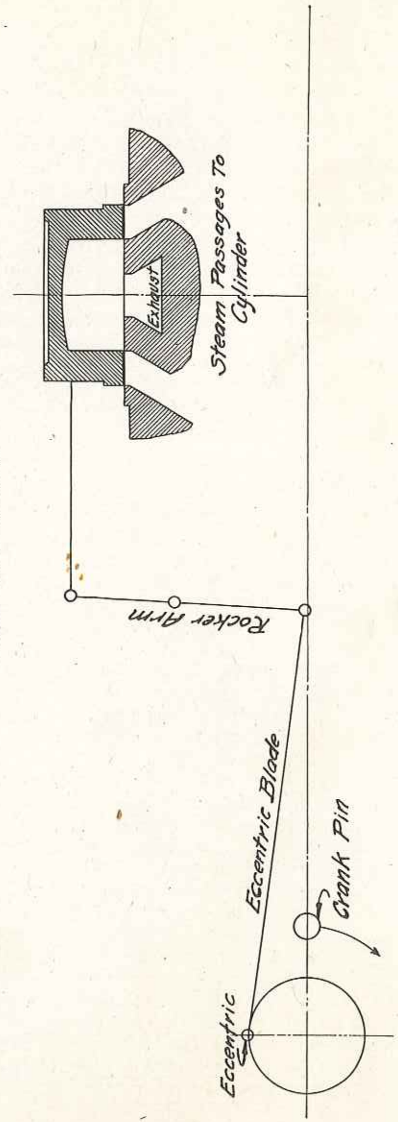


FIG. 23.
Indirect Valve Motion.

In Figs. 22 and 23, the ports to the ends of the cylinder are closed when the crank pin is on dead center, and in some cases where valves are constructed with outside lap the same condition exists. If it is desired however, in order to provide a cushion for reciprocating parts, during the time they are stopping at the end of the stroke, and also to give the engine more power at the beginning of the reverse stroke, the eccentric may be further advanced on the axle, so to begin opening the steam port to the cylinder before the crank pin reaches dead center. The amount the valve has opened the steam port, when the crank pin reaches dead center is known as "lead."

The valves on some locomotives are so constructed that when they are placed on the center of their travel the exhaust edges of the valve overlap the bridges between the steam ports and exhaust cavity. The amount the valve overlaps these bridges is known as "inside lap" or "exhaust lap."

Valves, in other cases, are constructed so that the exhaust edges fail to reach the bridge, when located centrally on their seats, in other words, when the valve is on center, there is a small opening from each end of cylinder to the exhaust. The amount the valve lacks of covering the steam ports when on center is known as "inside or exhaust clearance."

The cylinder is also described as having clearance. This, however, is known as the space between the piston and cylinder head, when the piston is at the end of its stroke, and also includes the steam ports between the cylinder and the lower face of the valve. Cylinder clearance should, therefore, not be confused with clearance in the main valves.

It is necessary on locomotives to have two eccentrics for each valve in order to provide for moving in either direction, one for the forward and one for the backward motion. The eccentric, for the backward motion, is placed opposite the forward motion eccentric, it being moved from the position of 90 degrees from crank pin a sufficient amount, to overcome the lap of the valve, and provide the lead opening, in the same manner as the forward motion eccentric.

Instead of the eccentric blades being connected direct to the rocker arm or valve stem, however, they are connected to the top and bottom of a link. The link is formed as an arc of a circle, the center being the center of the axle on which the eccentrics are located. Without the link it would be necessary to change the blade connections at the rocker arm or valve stem each time the engine was reversed, so the link provides an easy way of making this change.

The Stephenson valve gear is located between the frames, as shown in Fig. 24, and consists of four eccentrics fastened to the driving axle and which revolve with the axle. The eccentrics are merely discs fastened rigidly to the driving axle. the hole through the eccentric which receives the axle, being bored out of center sufficiently so that as the axle revolves the eccentric will produce a back and forth motion similar to a crank. This motion is transferred to the eccentric rod 2, which is fastened to the eccentric strap 3, which surrounds the eccentric 4. The eccentric rods fasten also to the links 1, one eccentric rod fastening to the top of each link, and the other to the bottom. The motion of the eccentric rods is therefore transferred to the links. Inside the slot in the link is fastened a sliding link block 7, which is attached to a rocker arm 8, the motion of the link block is therefore transferred to the valve rod 11 through the rocker shaft 9 and the arm 10 to the valve 12.

Assuming that the reverse lever is moved to the forward position in its quadrant, this moves the reach rod 26 and the reverse shaft 24, carrying with it the reverse shaft arm 23, and link hanger 6. As the link hanger 6 is attached to the center of the link, it causes the link to be moved downward so that the link block will be in line with the eccentric rod connection at the top of the link. The eccentric rod in this case being connected to the eccentric which is adjusted in its relation to the crank pin, as to cause the locomotive to run forward.

If the reverse lever is moved to the backward position in its quadrant, the link will be raised so that the link block will be in the bottom of the link and almost directly opposite the eccentric rod which is connected to the other eccentric. This eccentric being so set in relation to the crank pin as to cause the locomotive to run backward.

A locomotive has two engines, one for each side. It has also two eccentrics for each side, both eccentrics being connected to the link and valve rod as described above. In order that it will be possible to cause the locomotive to start at any time the driving wheels are fastened rigidly to the driving axles in such a position that when the crank pin on the right is on the forward dead center, which is on a horizontal line drawn through the cylinders and center of the driving axle. The crank pin on the opposite side will be on the top quarter, or one quarter of a turn behind the crank pin on the right side which is on its dead center. Referring to Fig. 24, supposing the crank pin on the left side to be in its upper position, or what is designated as the top quarter, and that the reverse lever be placed in its forward position, the movement of the link in this case would cause the valve to move to a position to admit steam through steam passage 14, behind the piston in the cylinder to force the piston forward.

The piston 18 being rigidly connected to the crosshead 33, by its piston rod 19, moves the crosshead forward with it. Since the main rod 20 connects the crosshead to the main crank pin 34, the crank pin is also moved forward, causing the driving wheel to revolve. As the driving wheel revolves, it causes the axle to revolve, carrying with it the eccentrics 4. The movement of the eccentrics now being transmitted to the eccentric rods, links, valve rod and the main valve in the steam chest. As the main crank pin passes its front central position, the main valve reaches a position to exhaust to the atmosphere, the steam which has been used to move the piston forward, at the same time admits steam from the steam chest to the cylinder in front of the piston, causing the piston to be pushed backward in its cylinder which,

of course, transmits this motion through the piston rod, crosshead and main rod to the crank pin, which is thus forced by its lower-most or bottom quarter position to its back center. At this point the valve assumes a position to exhaust to the stack the steam used to force the piston backward and again admits steam behind the piston.

If the reverse lever should be placed in its backward position, the operations described above would be reversed. It can be seen from the above description that while one crank pin is on its dead center, (in which case, of course, the piston and crosshead would be unable to move it either backward or forward, on account of the main rod being on a straight line through the cylinders and driving axle) the crank pin on the opposite side is on either its top or bottom quarter so that the full power of the piston in its cylinder is exerted to either pull or push on the crank pin, causing the driving wheel to revolve, and since the driving wheels are rigidly attached to the axles, the crank pin on the opposite side would be moved away from its central position toward its top or bottom quarter.

VALVE LEAD

The lead opening given a valve is for the purpose of insuring that the pressure in the cylinder will be equal to the pressure in the steam chest when the piston starts to move.

Fig. 25 illustrates the position of the main valve with the reverse lever in full gear and on center. The circle "C" represents the path of the eccentrics around the axle, "D" is the crank pin, "E" is the eccentric rods, "G" the link, "I" the rocker arm, "J" the valve rod and "K" the main valve. "L" is the steam ports leading to the cylinder and "M" the exhaust port leading to the exhaust nozzle. When the link is in the position shown by the dotted lines and indicated by "H," it will be noted that the eccentric rod "E" has moved to the position marked "F," and that the end of the rod at the link connection has moved back slightly on account of it being fastened at the eccentric and the opposite end traveling in a circle. This movement carries the link to this position and with it the rocker arm, and moving the valve forward to reduce the port opening. The distance "A" shows the port opening when the reverse lever is in full forward motion and the distance "B" shows the port opening when the reverse lever is moved to the center of its quadrant.

As the reverse lever is moved toward its central position, the link block traveling in the curved slot of the link, moves the valve slightly so that the steam port is opened a greater distance, thus it can be seen that a greater amount of lead opening is had when the reverse lever is near its central position than is the case when in its full forward or backward position. If, therefore, the reverse lever is placed in its central position in the quadrant while the locomotive is moving, the valve will be moved to open the port at each end of the cylinder when the piston reaches the end of its stroke. The opening to the cylinder at this time, however, will only equal the lead opening so that steam will be admitted to the cylinder through a very small port opening, and will follow the piston for only a very short distance before the valve closes the admission port.

LEAD ADJUSTMENT

The amount of lead opening given the valve may be increased or decreased by moving the eccentrics upon the axle. Changing the lead opening by changing the length of the eccentric blades or valve rods will cause the lead to be changed unequally, that is, what is added on at one end will be taken off at the other, and vice-versa. Ordinarily, the eccentric rods are bolted to the eccentric straps with bolts having a neat fit both in the eccentric strap and the eccentric rod holes. Therefore, the eccentric rods in this case are not adjustable by simply loosening the bolts.

In some cases the center hole in the eccentric strap is oblong to permit of the eccentric rod being adjusted to the proper length when setting the valves. After this length is found the balance of the eccentric rod bolts are fitted tightly.

STEAM DISTRIBUTION AND REVERSING

If the piston is at the front end of the cylinder, on account of the crank pin being on its dead center, and the reverse lever is placed in either its full forward or backward position, the main valve would be moved to a position to open the steam port to the amount of lead given the valve, to admit steam to the front end of the cylinder, in accordance with the manner in which the valve gear was adjusted. Steam would, therefore, be admitted into the cylinder to cause the piston to move to the back end of the cylinder. As the piston moves from the end of its stroke the main valve would be moved to open its port until the maximum port opening is obtained, or until the steam port is wide open. The motion of the valve would then be reversed, and the valve would start to close the port leading to the cylinder. Under the above conditions steam from the valve chamber would be allowed to follow the piston from the beginning of its stroke until it has traveled about three-quarters of its full stroke, at which time the port would be closed. The steam would then expand until the valve has moved far enough to open the exhaust port, when the steam would be exhausted from the cylinder to the atmosphere. As the piston completes its stroke and reaches the back end of the cylinder, the valve would have moved to a position to open the steam port equal to the amount of lead given the valve for that end of the cylinder, when the piston would be forced to the front end of the cylinder, the valve opening and closing the ports in the same manner as before.

It will be noted from the above description that as the piston travels away from the cylinder head at either end, the valve is caused to open the steam port wider than is the case when the piston is at the extreme end of its stroke. Therefore, when the crank pin reaches a position about mid-way between its forward or back dead center, and the piston is near the center of the

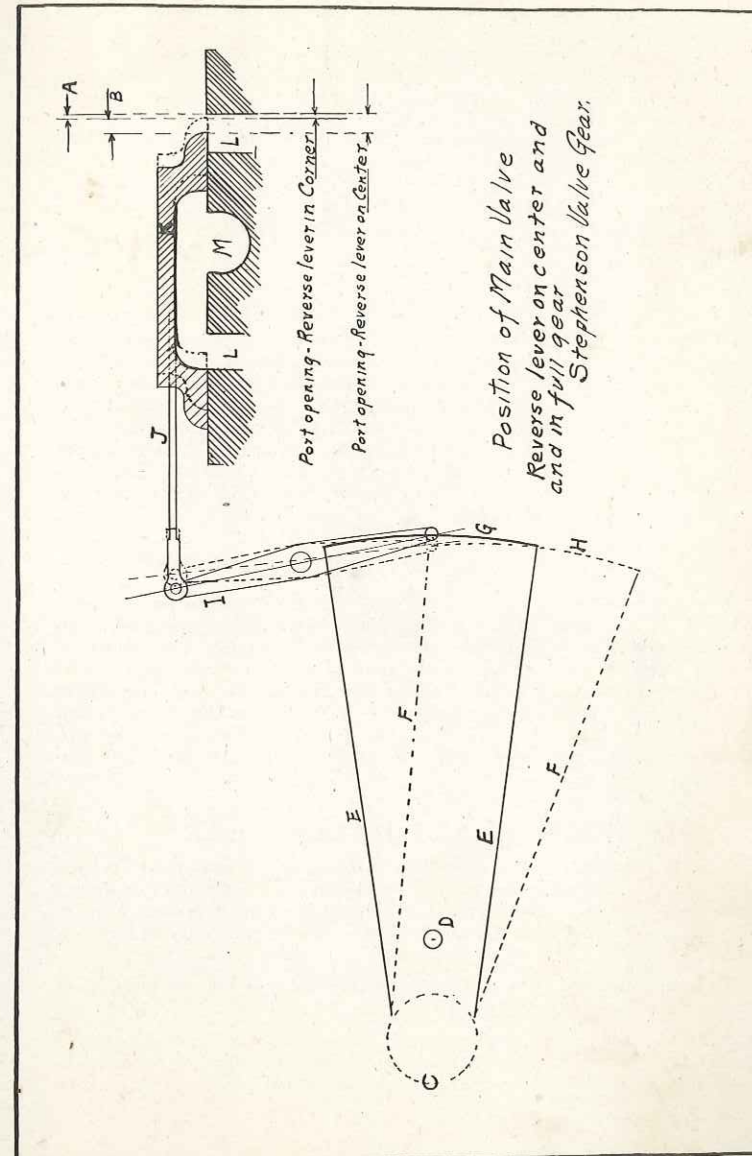


Fig. 25.

cylinder, the maximum steam port opening to the cylinder is obtained. Therefore, if the crank pin is near its bottom quarter position and the reverse lever is placed in full forward gear, the valve would be moved to a position to open the steam port wide at the front end of the cylinder. Moving the reverse lever to the full backward position in its quadrant would cause the steam port leading to the back end of the cylinder to be opened wide, admitting steam to the back end of the cylinder, or if the reverse lever was moved to the central position in its quadrant, the valve would be moved to its mid-travel or central position on its seat, and no steam would be admitted to either end of the cylinder.

CYLINDER COMPRESSION

When the exhaust port is closed before the piston reaches the end of its stroke the steam left in the cylinder fills the clearance space, any movement of the piston towards the end of the cylinder will then compress the steam in the clearance space. Provision is made so that compression will take place in order that the pressure in the cylinder will be nearly equal to the steam chest pressure, when the valve opens to admit steam. The compression also serves to cushion the reciprocating parts as they reach the end of their stroke.

DIRECT AND INDIRECT MOTION

If the valve motion is indirect and the main valve has outside admission, the forward motion eccentric would follow the main crank pin about 90 degrees. If the valve is inside admission the forward motion eccentric would lead the main crank pin about 90 degrees. With direct valve motion and an outside admission valve, the forward motion eccentric would lead the main crank pin about 90 degrees. With an inside admission valve the go-ahead eccentric would follow the main crank pin about 90 degrees.

WALSCHAERT VALVE GEAR

The Walschaert valve gear differs from the Stephenson in that it is placed entirely outside the frames of the locomotive, making it more accessible for lubrication, inspection and repairs. Motion for this gear is taken from the main crank pin and the cross-head.

In order to give the student a clearer idea of the principles of the gear, three cuts are used Figs. 26, 27 and 28.

Fig. 26 shows the gear with but an eccentric rod connected directly to the valve stem. With the valve shown, having outside admission, the eccentric crank leads the main pin approximately

90 degrees and if it were not necessary to provide means for reversing the engine, this is all the gear that would be necessary, as to provide for overcoming the lap of the valve and the desired lead, all that would be necessary would be to move the eccentric crank a sufficient distance ahead to do this.

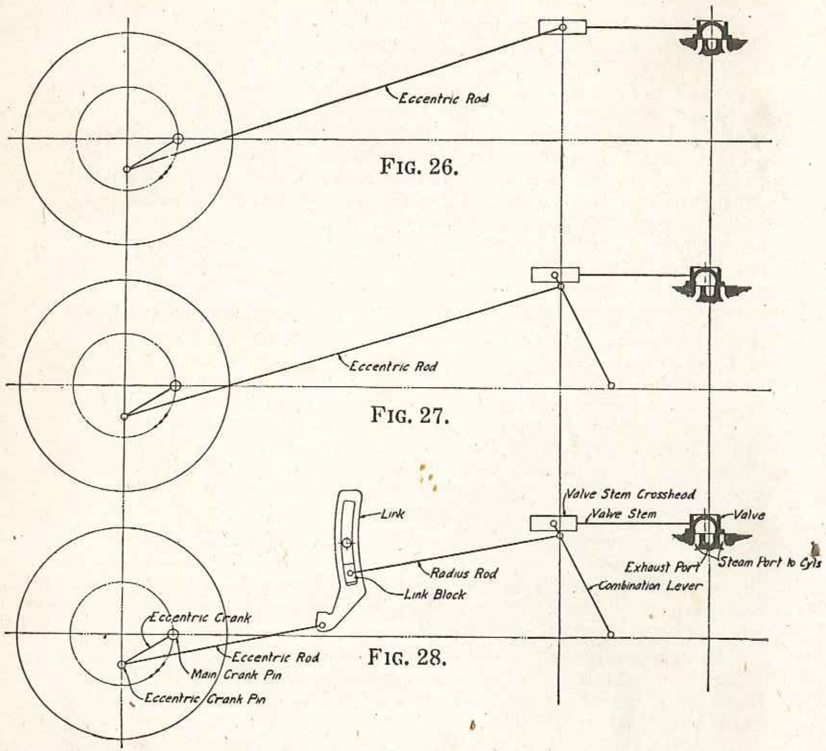
Fig. 27 shows the same gear with the introduction of the combination lever, sometimes called the "lap and lead lever" the bottom end of which is attached to the crosshead. It will be noted that in Fig. 26 the valve covered the port, leading to the forward end of the cylinder, the amount of the valve lap. In Fig. 27 by the introduction of the combination lever, the valve has been moved back sufficiently to open the port the amount of lead which is given the valve. It may readily be seen that when the engine moves and when the crank pin reaches the back center, that the crosshead will have moved the bottom of the combination lever to its backward position and that its angle will be reversed to bring about the same amount of valve opening to the back of the cylinders.

Fig. 28 shows the gear with the link and radius rod added and these additions provide the means of reversing; the forward end of the radius rod is connected to the combination lever and the back end to a sliding block within the link. The link is carried on trunions located at the center of its arc and is free to oscillate on these bearings so that when the radius rod and link block are in the bottom of the link the valve receives its motion direct from the eccentric crank and eccentric rod and it is common practice to construct the gear so that the engine will be in forward gear when the link block is at the bottom.

When the engine is reversed the radius rod and link block are raised to the top of the link and it can be seen that this reverses the motion of the valve and that it will travel in the opposite direction than the eccentric crank and rod and provide for the reverse movement of the engine.

The reversing shaft arm is connected to the radius bar in such a manner that the end of the radius bar connected to the link block may be raised and lowered as the reverse lever is moved back and forth in the cab.

The slot in the link, like that of the Stephenson gear, is not straight. The radius of the link slot equals the length from the center of the link block to the center of the combination lever pin, these two points are connected to the radius bar. Since the radius bar has a flexible connection to the combination lever, if the link is in a perpendicular position the link block may be moved from one end of the link slot to the other, carrying with it the radius bar. However, that end of the radius bar attached to the link block would describe a circle corresponding to that of the link slot, consequently the opposite end of the radius bar would remain stationary and no movement would be imparted to the valve rod or valve. This is the condition when the crank pin is on either its forward or back dead center; it will thus be seen that the reverse lever may be moved from extreme full forward to extreme full backward position without changing the position of the main valve upon its seat.



Diagrammatic Illustration Showing Valve Events of the Walschaert Valve Gear Without and With Combination Lever.

VALVE LEAD

The amount of lead opening which the valve has when the crank pin is on either dead center, in which case the link stands in a vertical position, would be the same with the reverse lever in any position in its quadrant, therefore, moving the reverse lever from its extreme full forward or backward position toward the center would not change the lead opening.

It will be found in some cases that the valve rod is connected to the top of the combination lever and the radius bar connection is between the valve rod connection and the crosshead connection to the combination lever. If the valve is inside admission, the radius rod is connected to the top of the combination lever above the valve rod. If the main valve is outside admission the radius rod is connected to the combination lever below the valve rod connection. This would simply reverse the position of the main valve with relation to the steam port in order that the valve will open the steam port at the proper end of the cylinder.

As stated before, when the main crank pin is on either dead center, the lead opening from the steam chest to the cylinders is the same with the reverse lever in any position in its quadrant. This is due to the fact that the combination lever moves the valve an amount sufficient to open the steam port for the amount of lead given the valve at both ends of the cylinder, without any motion whatever being transmitted from the crank pin to the valve rod. With the valve on the center of its seat, its outside edges overlap the outside edges of the steam ports, the combination lever then must move the valve on its seat equal to the amount of valve lap, plus the lead opening. It can be said, therefore, that the combination lever overcomes the amount of lap and lead given the main valve.

When the link block is moved away from its position in the center of the link slot, any movement of the link back and forth is transmitted to the radius bar, which moves the top end of the combination lever with it, transmitting this motion to the valve rod and the main valve. The duty of the crank arm is therefore to transmit motion to the main valve so that it will be moved back and forth on its seat to admit steam to, and exhaust it from, the cylinder at the proper time, in relation to the piston movement in its cylinder. In order to increase or decrease the lead opening with the Walschaert valve gear it is necessary to change the distance between the radius bar connection and the valve rod connection at the combination lever, or the distance from the radius rod connection and the connection of the combination lever to the union link.

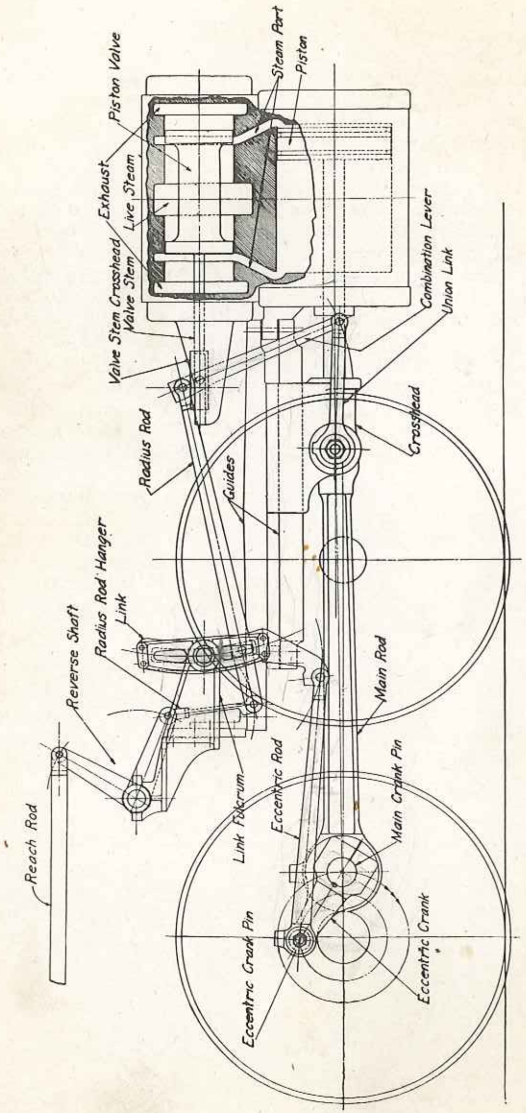


FIG. 29.
Walschaert Valve Gear Arrangement.

REVERSING

In Fig. 29 the main crank pin is shown in the front center position and the link standing perpendicular. Now suppose the crank pin to be moved to the bottom quarter position, the eccentric crank would move the bottom of the link forward and the top backward. If then the reverse lever was moved to its full gear forward position, the link block and back end of the radius rod would be lowered, moving the radius rod forward. This movement would be transmitted to the top of the combination lever, the valve stem and valve. The valve would therefore be moved forward to open the steam port to admit steam to the front end of the cylinder and connecting the back end of the cylinder to the exhaust. If the reverse lever is moved to its full back gear position, the link block and back end of the radius rod would be raised to the top of the link. This would cause the radius rod to be pulled backward, moving with it the combination lever, valve stem and valve, moving the valve to a position to admit steam to the back end of the cylinder and connecting the front end of the cylinder to the exhaust.

BAKER VALVE GEAR

The Baker valve gear is an outside gear, similar to the Walschaert gear, except that it has no reversing links or sliding blocks, the motion is derived from the crosshead and the eccentric crank arm attached to the main crank pin, the same as the Walschaert valve gear. This gear is shown on Fig. 30.

In place of the reversing link such as is used on the Stephenson and Walschaert valve gears, the Baker valve gear employs a bell crank and a system of hangers and rods. A combination lever 9 connects to union link 10 at its lower end and union link connects to cross-head 1 while top end of combination lever connects to valve crosshead 13 and front end of valve rod 12. The eccentric rod 5 connected to the eccentric crank arm 4 also connects to what is called gear connecting rod 6, the top end of gear connecting rod being connected to the horizontal arm of bell crank 3, the vertical arm of bell crank is connected to back end of valve rod 12. Approximately midway between eccentric rod connection and bell crank connection of gear connecting rod is connected a hanger called radius bar 2, the gear connecting rod is therefore free to swing back and forth from movement imparted by the eccentric crank through the eccentric rod. As the crosshead moves back and forth the valve rod 12 is moved back and forth by the combination lever 9. The point of suspension of the radius bar 2 is such that as it is swung back and forth by the gear connecting rod, the connecting rod is lifted up and down, this motion is imparted to the horizontal arm of the bell crank 3, which causes the lower arm of the bell crank to swing back and forth, therefore motion is imparted to the valve rod 12, both by the crosshead and the eccentric rod. The radius bar is attached to the reversing yoke 17 which in turn is attached to the reversing shaft 15 operated by reach rods 8 and 11 and the usual reversing lever in cab.

When the crank pin is on either dead center, a movement of the crosshead from one end of its guides to the other causes the valve to move the amount of lap given the main valve, plus the lead; the same as for the Walschaert valve gear. When the crank pin is on either front or back dead center the lead to the cylinder is the same for all positions of the reverse lever. The Walschaert gear and the Baker gear therefore have a constant lead. This means that moving the reverse lever from the full forward or backward motion toward the center does not change the amount of lead opening when the crank pin arrives at either dead center.

REVERSING

With the Baker valve gear the essential difference in the arrangement of the gear for inside and outside admission valves is that for an outside admission valve the reverse yoke is in front of bell crank and for inside admission valve the reverse yoke is behind the bell crank and the bell crank being reversed.

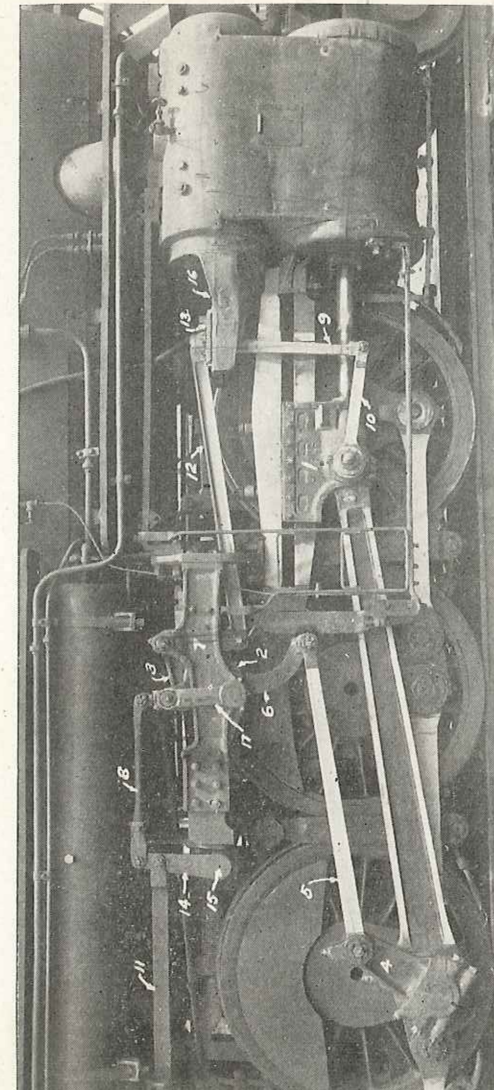
Referring to Fig. 30. If the crank pin is on the bottom quarter position and the reverse lever is moved to its full forward gear position the reverse yoke will lower the radious bar and also the horizontal arm of the bell crank. The lower perpendicular arm of the bell crank will be moved backward, transferring the motion to the valve rod 12, combination lever 9, valve crosshead 13, valve stem 16 and the main valve. The main valve would therefore be moved to admit steam to the front end of the cylinder and connecting the back end of the cylinder to the exhaust. If the reverse lever is moved to the full back gear position the reverse yoke would raise the radius bar and the horizontal arm of the bell crank moving the lower arm of the bell crank forward, this motion is transferred to the main valve, which is moved to a position to admit steam to the back end of the cylinder and connecting the front end of the cylinder to the exhaust.

VALVES

Common Slide Valve

The ordinary slide valve commonly known as the "D" type valve, on account of its shape, has a cavity in its center to control the exhaust steam from the cylinders.

The common unbalanced "D" slide valve is subjected to considerable pressure on its seat, on account of the steam pressure acting upon its entire upper surface. This presses the valve tightly on its seat, causes the valve and seat to wear rapidly and also increases the friction between the valve and seat, and the difficulty of lubricating the same. Oil should therefore be fed to the valves regularly and in sufficient quantity to insure proper lubrication. When the valves get dry, due to lack of lubrication or on account of working water through the cylinders, the work of the valve gear is increased considerably, this causes increased



1. Main crosshead
2. Radius bar
3. Bell crank
4. Eccentric crank arm
5. Eccentric rod
6. Gear connecting rod
7. Valve gear frame
8. Intermediate reach rod
9. Combination lever
10. Union link
11. Reach rod
12. Valve rod
13. Valve crosshead
14. Reverse shaft arm
15. Reverse shaft
16. Valve stem
17. Reversing yoke

FIG. 30. Baker Valve Gear.

wear on all moving parts, tends to distort the various parts of the gear, making the engine sound lame, reducing the power of the engine and increasing the consumption of fuel and water.

In order to overcome these disadvantages, as far as possible, a type of slide valve known as the balanced slide valve was developed from the ordinary "D" type valve. This type of valve is shown by Fig. 31. The slide valve shown in Fig. 31 is balanced by applying strips along its upper edges which bear against a plate on the steam chest cover, and fit closely in grooves cut in the top of the valve's body. The space on top of the valve between the strips is connected to the exhaust passage, thus the pressure in the steam chest is excluded from a greater part of the valve's surface, reducing its resistance to movement on account of the reduced friction and the ability to better lubricate the wearing surfaces.

The strips above mentioned fit closely against each other at the ends and also fit the grooves on their inside edges, the steam pressure tending to force them together, thus making a steam tight joint. Springs underneath the strips provide for holding them against the pressure plate at all times.

In Fig. 31 is shown the balance strips and balance plate as used with an ordinary balanced slide valve. In the plain slide valve the port through the valve and the balance strips and plate are omitted.

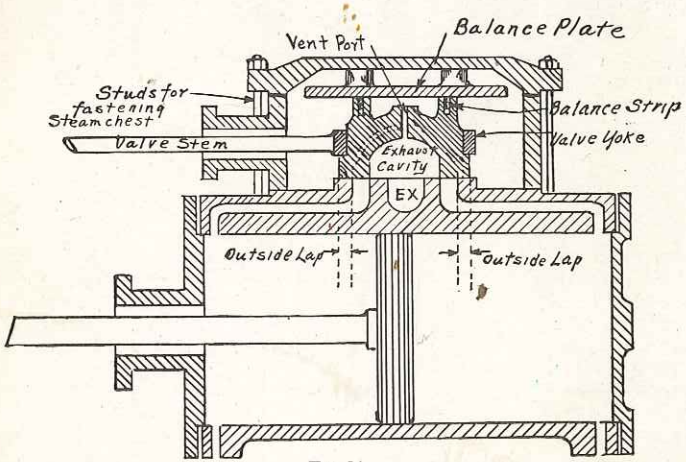


FIG. 31.
Balanced Slide Valve.

PISTON VALVE

A piston valve is of circular cross-section, having two or more heads or spiders for directing steam to the proper ports. The different heads are fitted with packing rings similar to and for the same purpose as the rings on the main steam piston. It operates in a cylindrical chamber or bushing and will give greater port opening for the same movement than will a slide valve of equal weight. Such a valve is clearly shown in Fig. 32.

If the live steam from the boiler passes to the cylinders between the two heads of a piston valve, the valve is of the inside admission type. However, if the steam passes to the cylinders at the ends of the valve, the valve is of the outside admission type.

Slide valves are attached to the valve motion by a valve yoke, which passes around the slide valve and attaches to the valve stem, while a piston valve is connected to the valve motion by a valve stem which passes through the valve somewhere near its center in the same manner as fastening the ordinary piston to the piston rod.

LOCOMOTIVES EQUIPPED WITH LIMITED CUT-OFF VALVES

With the ordinary construction of valves and valve motion the maximum amount of "lap" which can be given a valve is governed by the shortest cut-off, when the reverse lever is in full gear, at which the locomotive will start its train. In other words, if, in an effort to provide means of securing the maximum amount of expansive force possible from steam, by giving a valve excessive lap, the admission of steam to the cylinder is thereby cut-off a greater distance before the piston has completed its stroke and if this is carried beyond certain limits the engine may stop, with the crank pins in a position where effective steam pressure will not be admitted to start. If the locomotive is started and then the cut-off shortened by "hooking up" the reverse lever, with the ordinary valve motion, the port opening is thereby reduced so that the steam is not admitted to the cylinder in sufficient volume for pulling heavy loads at low speed.

Valve lap which provides for cutting off the admission of steam to the cylinder when the piston has moved 85% of its stroke, with the reverse lever in full gear, is generally considered the shortest cut-off practical to be used in general service with the ordinary valve gear.

A design of valve has been developed, however, which overcomes, in a measure, the conditions which prevented the use of valves having lap which provided for a shorter maximum cut-off. In this valve, sufficient lap is provided so that when the reverse lever is in full gear, steam will be cut off from entering the cylinder at as low as 50% of its stroke or when it has traveled one-half of the length of its cylinder.

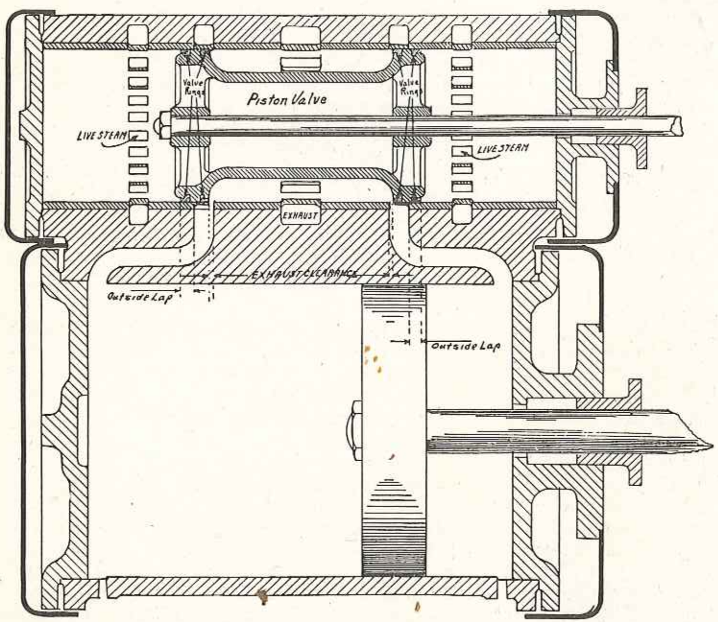


FIG. 32.

Piston Valve.

Locomotives equipped with limited cut-off valves are given long valve travel, the size of cylinder is either increased, or the boiler pressure is increased, above that which would obtain with ordinary valves.

After the locomotive is in motion, on account of the long valve travel a wide port opening is obtained in the early part of the stroke, and in starting trains, or pulling heavy trains at low speeds, where it is necessary to work the reverse lever well down in the quadrant a heavy volume of steam is admitted quickly to the cylinder, and although it is cut off earlier in the stroke, provides as high an average pressure during the entire length of stroke as the older type of valve. In this manner, although the pressure is either higher or the volume greater, the greater amount of expansion force of the steam, being utilized, effects a saving in the amount of steam necessary to be supplied by the boiler.

CYLINDER ARRANGEMENTS

The arrangement of cylinders differs for the various designs of locomotives, the simple locomotive has only two cylinders, one on each side, in which case steam which is used to force the piston from one end of the cylinder to the other is then exhausted through the valve to the exhaust ports in the cylinder saddles and to the smoke stack and the atmosphere. The cylinder saddle is that part of the cylinder casting between the frames to which the front end of the boiler is attached.

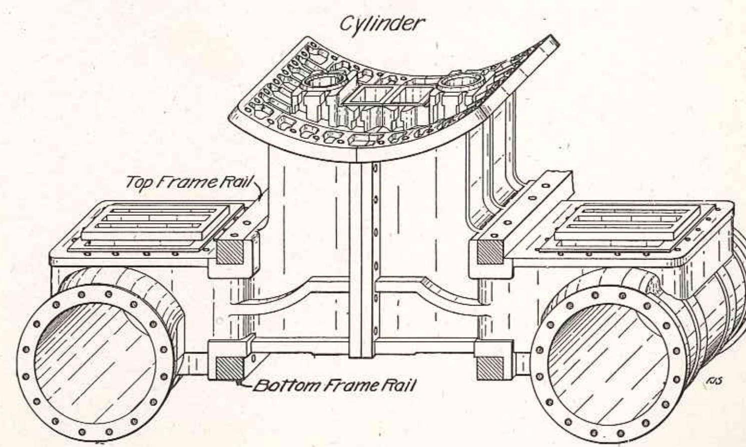


FIG. 33.

Cylinder Arrangement with Slide Valve.

It can be seen from this description that the simple locomotive uses steam only once after it is admitted to the cylinder. Figs. 33 and 34 show typical simple cylinders. The cylinders of Fig. 33 are for a slide valve locomotive, that of Fig. 34 are for piston valves.

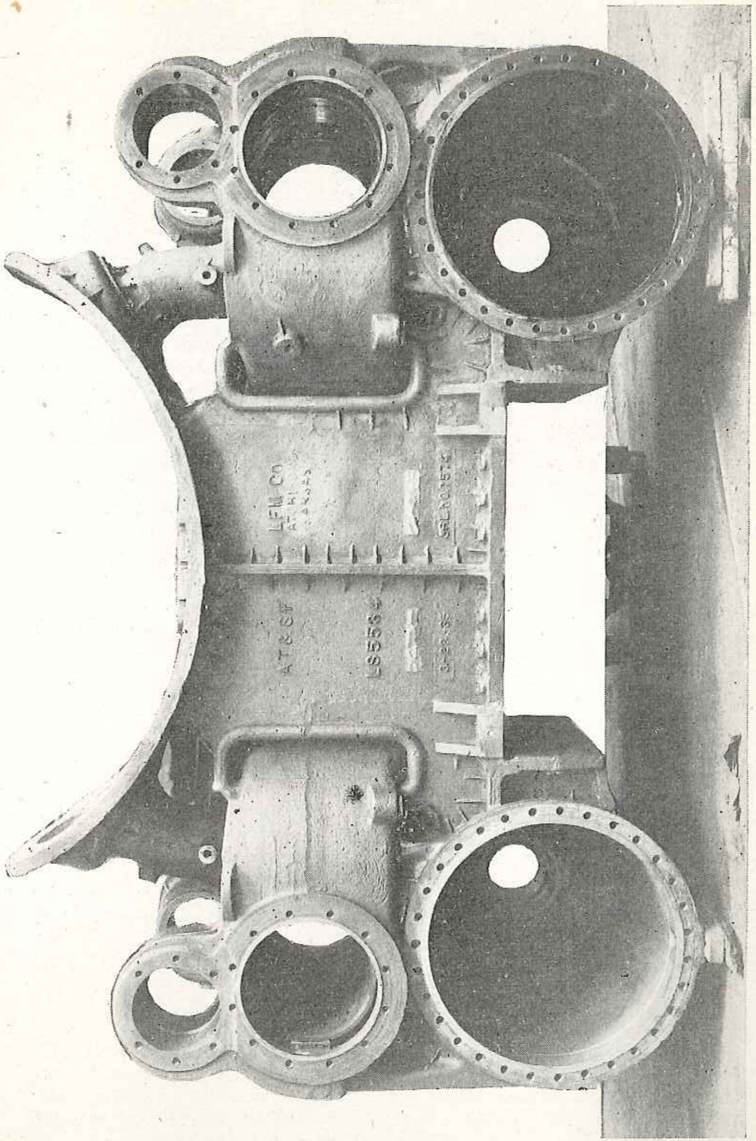


FIG. 34.
Cast Steel Cylinders with Piston Valve and By-pass Valve.

LOCOMOTIVE FRAMES

The main locomotive frame is the foundation upon which rests the boiler and cylinders, the frames being supported over the driving axles and truck wheel axles by a system of springs.

The main frame is comprised of two heavily built systems of rails, one on each side just inside the driving wheels. In order to hold them rigidly in place they are fastened solidly to the main cylinder saddle casting, which supports the front end of the boiler. At the rear end they are fastened together rigidly by a foot plate or deck casting, and with modern locomotives, a number of intermediate frame braces are applied. This is particularly true on locomotives having the valve gear outside the frames which permits plenty of room between the frames for applying substantial braces from one frame rail to the other.

Usually that part of the frame to which the cylinder saddle is bolted has offsets into which is fitted the corners of the saddles, and it is the practice to apply a tapered key between the offset in the frame and the cylinder saddle. This key is driven in tightly in order to hold the cylinder saddles firmly in place and prevent their movement back and forth, however, should these keys become loose or lost, a noticeable pound may occur on that side of the locomotive. Such keys should be maintained in place and tight, in order to reduce the shearing strain on the frame bolts securing the cylinder saddles to the frame.

The more modern locomotives have the entire frame and cylinders cast in one piece which makes the frame stronger and more rigid than the frames which are built in sections as described above. Fig. 35 shows a one-piece frame and cylinder casting for a 3460 class locomotive.

The boiler is, of course, secured to the frame at the smoke box, by bolting it rigidly to the main cylinder saddle casting. The firebox end of the boiler rests upon brackets attached to the frame, which are called expansion brackets or furnace bearers; in such a manner that the back end of the boiler may move forward or backward by sliding on the above mentioned brackets. This construction is to provide for the expansion and contraction of the boiler, as the boiler is longer when hot than when cold.

The expansion bracket, or furnace bearers, located at the firebox end of the boiler, are so arranged that while they hold the back end of the boiler in place, they provide for that end of the boiler to move back and forth to take care of the lengthening of the boiler due to expansion when it is hot. These parts should be maintained in good order and lubricated, to provide for a free movement of the boiler, with respect to the frame, otherwise there is a possibility of loosening or breaking the expansion brackets or of causing leaks in the boiler seams, particularly at the throat sheet, mud ring, staybolts and flues. In some types of locomotives, with deep fireboxes which set down between the frame, the expansion brackets are placed on top of the frame and secured to the side sheets, such brackets be-

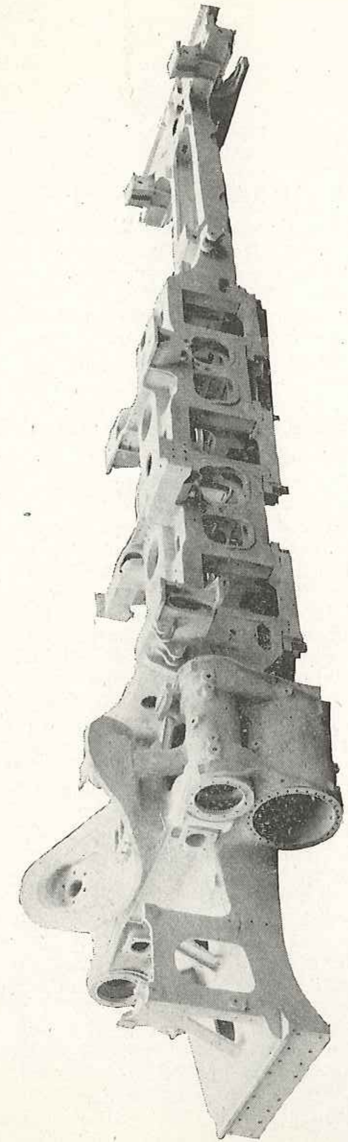


Fig. 35.
Cast Steel One-piece Frame and Cylinders.

ing built up in the form of angle irons. In other cases the firebox end is supported by pads which loop around the frame, being fastened to the firebox sheets above and below the frame.

In the case of a broken frame it is advisable not to attempt to handle anything but a very light train, particularly if pounding takes place when the locomotive is working. Locomotives with broken frames must not be handled dead in train.

PEDESTAL BRACES OR BINDERS

Fitted in the bottom of the frame jaw is what is termed a pedestal brace or binder, for the purpose of preventing the jaws from spreading and to hold the shoes and wedges in place. The shoes are snugly fitted between the above mentioned binder brace and the top of the frame jaws to prevent them from working up and down with the driving box. The pedestal brace or binder should be kept absolutely tight to prevent working of the frame jaws.

DRIVING BOXES, SHOES AND WEDGES

Jaws are provided in the main frame into which fit the driving boxes which rests upon the driving axles. These driving boxes are free to move up and down in the jaws. In order to care for the wear of the driving box faces and prevent wearing the jaws in the main frame, also to provide for maintaining the driving axles in proper alignment with the frames, a metal shoe is interposed between the driving box face and the frame. On the opposite side of the driving box the frame jaw is tapered, that is, the jaw is wider at the bottom than at the top. Another metal shoe is also provided on this side of the driving box, which is called a driving box wedge. This wedge conforms to the face of the box and to the taper of the frame jaw. Raising this wedge between the frame jaw and driving box forces the driving box against the shoe on the opposite side. This provides for fitting the driving box closely in each side of the frame jaw and also permits of taking up any lost motion in the driving box faces due to wear.

On some older locomotives the wedge fitted between the driving box and the frame is so constructed that it may be moved up and down by a wedge bolt extending through the binder brace. Turning the wedge bolt nuts, fitted to the wedge bolts, causes the wedge to be raised or lowered in the same manner as operating a screw jack, that is, if the nut on top of the binder is turned in the direction to raise the wedge bolt, after loosening the nut at the bottom, the wedge will be forced upward. If, however, the nut at the bottom of the wedge bolt is turned in a direction to pull the wedge bolt down, after loosening the top nut, the wedge will be pulled downward. After the wedge has been located in the desired position, screwing both the top and bottom wedge bolt nuts tightly against the binder securely locks the wedge in that position.

The driving box is free to move up and down between the

driving box shoe and wedge, and since the driving boxes, shoes and wedges are all of metal, the wearing surfaces must be regularly lubricated, in order to reduce the wear and to provide for free movement of the parts.

All driving boxes, even those having grease cellars, are provided with oil holes leading from the cavity on top of the box down to the shoes and wedges and the waste on top of the boxes should be oiled as well as that applied directly on the shoes and wedges.

On most modern locomotives, the wedge bolt hole through the binder or pedestal brace is drilled and tapped, the wedge bolt being screwed into this hole. In such cases it is necessary to turn the wedge bolt in order to raise or lower the wedge. A jam nut is applied to the wedge bolt which may be loosened to permit of making necessary adjustment, after which the nut is screwed tightly against the binder or pedestal brace to firmly lock the wedge bolt in the desired position.

In adjusting wedges to take up lost motion it is necessary that the driving box be forced against the driving box shoe, otherwise the wedge may be moved up tightly between the frame and box and still leave some lost motion in the driving box between the shoe and wedge. In order to accomplish this the crank pin may be placed on the top quarter and the throttle opened slightly in order to pull the driving box tightly against the shoe, the reverse lever to be placed in either the forward or back motion, depending on whether the wedge is located in front of the driving box or behind it. Ordinarily the wedges are located behind the driving box. In order to avoid blocking the locomotive to accomplish this, cut out the driving brakes and fully apply the tender brakes. The locomotive should always be upon a piece of straight level track when preparing to set up wedges. Throttle should be closed and cylinder cocks and globe relief valves opened before going under locomotive.

In setting up the wedges consideration must be given to the temperature of the driving box. If the boxes are at normal running temperature, after the locomotive has just been run a considerable distance, which is the best time for setting the wedges, the wedge may be adjusted closer than is the case if the driving boxes are cold and locomotive has been standing for a considerable period of time. It must be remembered, of course, that when the driving box warms up it expands and tends to tighten itself between the two faces of the driving box shoe and wedge.

If the wedge has been set up too tight, or the shoe and wedge faces are not properly lubricated, the driving box will not move freely between the shoes and wedges. This may cause driving box to heat up badly on account of the load shifting due to inequalities in the track. It also causes the locomotive to ride badly, and is more or less damaging to the journals, driving box and frame. In cases of this kind it is advisable to loosen the wedge as soon as possible and get it down so that the driving box may move up and down freely. If it cannot be pulled down with the wedge bolt, pull down as much as possible on the wedge bolt and then run the driving wheel ahead or back of the one with stuck wedge over a nut or other piece of metal. In some cases it may be necessary to slack off on the binder bolts, and run the wheel over the block, as stated before. In case the binder or pedestal brace is loosened it should be firmly tightened, after the wedge has been adjusted so that it will not stick again. In all such cases the binder bolts should be reported tightened on arrival at terminal. It may be possible some times to loosen a wedge after it has become stuck by applying some signal oil or kerosene oil to lubricate it, or pull down on the wedge bolt as far as possible, oil the shoe and wedge and proceed. The tendency of the driving box to move up and down will in many cases loosen the wedge soon after starting.

In case excessive lost motion in the attachment of the wedge bolt to the wedge interferes with holding the wedge in the desired position, a block may be placed between the wedge and binder brace to raise the wedge to the desired position, then pull down on the wedge bolt until the wedge is solid on the block and tighten the jam nut on the wedge bolt.

DRIVING AND TRUCK SPRING RIGGING

Resting on top of each driving box and reaching considerably above and spanning the top frame rail, is what is called a spring saddle. This spring saddle is so constructed that one leg of the saddle rests on top of the driving box outside the frame rail, the other leg resting on top of the driving box inside the frame rail. The driving spring then rests on the spring saddle. This provides for the driving box to move up and down in its jaw, carrying with it the spring saddle. To the ends of the driving spring are attached flat bars called spring hangers; these spring hangers attach either to the main frame or to the end of equalizing levers, or the equalizing levers are attached to the main frame at or near the middle of the equalizers. In this way the main frame is supported on the spring hangers, equalizers and springs, the spring saddles providing for the necessary movement of the driving boxes in the frame jaws to care for the action of the driving springs. This arrangement also permits the weight of the locomotive to be distributed among the various pairs of wheels so that each pair will carry its share and no more.

In some cases a four wheel truck supports the front end of the locomotive, this truck being located directly under the cylinder saddle casting. In such cases an independent system of spring rigging is included in the construction of this truck. It is also the practice on large locomotives, to apply a trailing truck behind the back driving wheels, to support the back end of the locomotive. When a trailer truck is used the spring rigging supporting the frame over the trailer is connected through a system of equalizing levers to the spring rigging over the driving boxes. When a two wheel truck is used at the front end of the

locomotive, the spring rigging of this truck is connected to the driving spring rigging through a system of equalizing levers. Fig. 36 shows the main frames and two systems of springs referred to above.

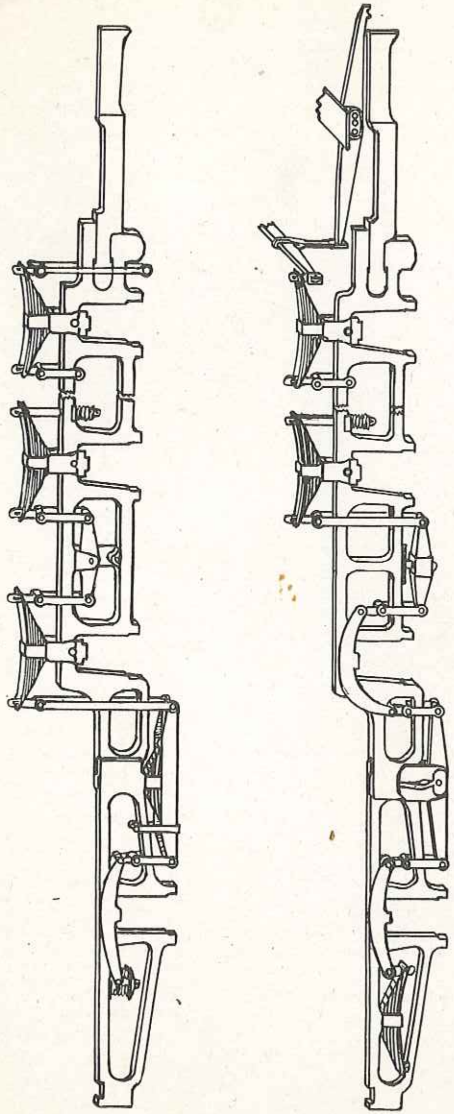


FIG. 36
Driving and Truck Spring Rigging Arrangements.

TIMKEN ROLLER BEARINGS

Right and left engine truck axle journal roller bearings are enclosed with a one-piece cast steel housing which takes in both bearings and is provided with two drain plugs, one under each journal, and an oil filling plug to each the right and left bearing located between truck frame approximately 4 inches from bottom of housing.

Right and left driving axle journal roller bearings are enclosed with a cast steel housing made up in two pieces, top half and bottom half, which are bolted together when applied and take in both right and left bearings. Housing is provided with a drain plug under each journal and also has an oil filling plug for each journal located between main frame approximately 4½ inches from bottom of housing.

Trailer truck axle journal roller bearings are equipped with independent cast steel housings for each right and left journal, and are provided with a drain plug at outside face of housing just below the lid, and are also equipped with an oil filling plug located in housing lid approximately 3½ inches from bottom of housing. Both the drain and filling plugs are locked with a wire applied through head of plug to prevent being lost.

Tender truck axle journal roller bearings are equipped with independent cast steel housings for each right and left journal and are provided with a drain plug at outside face of housing just below the lid, and are also equipped with an oil filling plug located in housing lid approximately 3 inches from bottom of housing. Both the drain and filling plugs are locked with a wire applied through head of plug to prevent being lost.

Drain plugs in all of the above housings are removed at regular periods by roundhouse forces for draining water from the roller bearing oil.

Oil level in all roller bearing housings is checked at regular periods by roundhouse forces and if found to be below prescribed minimum, roller bearing oil is added to bring oil level even with bottom of filling plug which is considered maximum oil level to be carried.

In case a roller bearing develops excessively high temperature while on road, if possible, without further damage to axle or roller bearing, the locomotive with train should proceed at reduced speed to first station. If this station is a roundhouse terminal the roundhouse forces should make a thorough inspection by checking temperature and oil level in housing and their findings will determine if locomotive is to continue or be replaced with another locomotive.

If there are one or more stations between the point where hot bearing is discovered and the next roundhouse terminal, and it is possible, without further damage to bearing or axle, the locomotive with train should proceed at reduced speed to the next station where the temperature should be checked by feel of hand. If it is found that locomotive can be operated at reduced speed to roundhouse terminal without further damage to axle or bearing and with less delay than procuring another locomotive then the locomotive with hot bearing should continue and a telegraphic or telephone report made to the next roundhouse terminal where arrangements will be made to furnish another locomotive.

If it is found that locomotive cannot be moved from point where hot bearing is first discovered without further damage to bearing or axle, then locomotive with train should proceed at reduced speed to first siding or nearest station and request made for locomotive to be furnished from the nearest roundhouse.

S. K. F. ROLLER BEARINGS

Engine truck axle, driving axle, trailer truck axle and tender truck axles equipped with S.K.F. roller bearings have independent cast steel housings for each journal bearing, except that the present independent driving axle journal housing are being replaced with a modified housing in which the upper half of housing takes in both right and left bearing.

Engine truck axle and driving axle housing are equipped with a drain plug at a bottom corner inside face of housing. In addition they are also equipped with a filling plug located at inside face approximately 4 inches from bottom face of housing.

Each trailer truck axle and tender truck axle housing is equipped with a drain plug and an oil filling plug, the drain plug being located at bottom outside face of housing and filling plug located in housing lid approximately 3½ inches from bottom of housing.

The drain plugs in all of the above housings are removed by roundhouse forces at regular periods to check for water in housings. The lubricating oil filling plugs are also removed at regular periods to check oil level in housing and if oil level is found to be less than prescribed minimum, then regular roller bearing oil is added to bring oil level up to bottom of filling plug hole, which is considered the maximum amount of oil to be carried in housing. The filling plug is then applied and both the filling plug and drain plug are wired through heads of plugs to prevent being lost.

The procedure for handling locomotives on road that are equipped with S.K.F. roller bearings that develop excessively high temperature should be the same as that for Timken roller bearings.

RADIAL BUFFER BETWEEN LOCOMOTIVE AND TENDER

Type "A" Radial Buffer

The Type "A" wedge and screw adjustable buffer must be adjusted so there is a total of $\frac{1}{16}$-inch slack between locomotive and tender on straight level track. If there is less than $\frac{1}{16}$-inch slack on straight level track, the faces of radial buffer will contact solid on curves causing binding, and may result in derailment of tender.

Adequate lubrication is to be maintained on all rubbing surfaces of type "A" radial buffer at all times.

Type "E" Radial Buffer

Type "E" radial buffer is designed to use on the tender portion two helical springs placed laterally in the pocket and working in conjunction with suitable bearing plates, spring seats and wedges to force the adjustable chafing plate forward, thus making the radial wearing faces contact under high compression at all times, resulting in dampening the shocks that take place between locomotive and tender.

The rubbing faces on type "E" radial buffer must be provided with adequate lubrication at all times.

BREAK-DOWNS—GENERAL

Engineer's Duty

An engineer's first duty in case of a break-down which necessitates stopping, is to see that the train is properly protected against other trains, and next to see that the main line is cleared as soon as possible, and proper report made, giving details of the trouble being experienced, with the probable length of time to get the locomotive moving and what work the locomotive will be able to perform after ready to proceed.

Should anything occur which would necessitate stopping a train for inspection of any parts which does not require a stop at once, the engineer must always consider his ability to start the train readily after making such stops, and should avoid, if possible, stopping at places where it is difficult to start, and should also, if possible, stop where there will be a clear view to the rear of the train for a reasonable distance.

Before disconnecting in the case of any break-down, determine how long it will take to put the locomotive in condition to move, what work the locomotive can do and whether another locomotive is readily available to take the train. Do not start to disconnect if it will cause additional delay after relief locomotive arrives before the work of disconnecting can be completed. In such cases only disconnect those parts necessary to provide for the locomotive being towed.

BREAK-DOWNS—STEPHENSON VALVE GEAR SLIPPED ECCENTRICS AND IRREGULAR EXHAUSTS

In case anything occurs to prevent the main valve from admitting steam to or exhausting it from the cylinder at the proper time, the exhausts will be irregular, in which case the locomotive is said to be lame. The most frequent causes of a locomotive being lame are: Eccentrics out of adjustment on the axle. Eccentric rods out of adjustment where fastened to the eccentric straps, rocker box loose on their supports; eccentric strap bolts loose; a cracked or broken valve yoke, if the locomotive has slide valves; or a broken valve or valve ring if the locomotive has piston valves; valve loose on valve stem or lack of lubrication which makes the valve very difficult to move on its seat. The link may be broken at one end. Do not confuse heavy and light exhausts for irregular exhausts, the locomotive may be square and still have one or more heavy exhausts, the others being normal.

In order to determine which eccentric is slipped, the reverse lever may be placed in full forward motion, applying the brakes and moving locomotive slowly. If the locomotive is square with the reverse lever in full gear, but the exhausts become irregular as the reverse lever is hooked up or moved toward the center, the trouble would be in the back-up eccentric. It may be possible to determine which side of the locomotive is at fault by watching the crosshead and listening to the exhausts. If the locomotive is square an exhaust should occur as the crosshead reaches either end of its guide and as it passes the center of the guide in both directions.

Under the present method of fastening eccentrics on the driving axle, a slipped eccentric is a rare occurrence. The axles have slots or key-ways cut into them as have also the eccentrics, and a steel key is fitted into these key-ways. The two halves of the eccentric are fastened together with substantial bolts, and set screws are also placed through the eccentric, which are screwed firmly against the axle. Should an eccentric move out of its proper position on the axle due to the key being out of place, or shearing off, the eccentric may be placed near enough to proper adjustment by moving it around until the two key-ways, the one in the axle and the one in the eccentric, are together. This will permit the locomotive to handle the train to terminal, where repairs can be made. It might be that the axle will have two slots or key-ways cut in it, in which case the proper key-way to use can be determined by noting the other eccentric on the same side to see whether the eccentric is set to follow the main crank pin or to lead it, in other words, the eccentric should be set on the opposite side of the crank pin and the same number of wheel spokes from the crank pin, the crank pin to be mid-way between the two eccentrics. The reason for more than one key-way being found in the driving axle is that the valve motion is sometimes changed on account of applying new cylinders which have different types of valves, one being arranged to admit steam to the cylinder from the center or inside of the valve, and the other admits steam to the cylinder from the ends or outside of the valve.

If both eccentrics are slipped set them in the same relation to the crank pin as the ones on the opposite side of the locomotive, and the same number of spokes in the wheel from the crank pin.

When an eccentric slips out of place the exhausts will be irregular, and since the crank pins are placed one quarter of a turn from each other, and an exhaust takes place each time the crank

pin arrives at the center, there should be an exhaust occur each time the crank pin arrives at the center and the top and bottom quarter. Watching the crank pin on either side as the locomotive moves slowly will locate the point at which the irregular exhaust occurs. There should be four exhausts for each revolution of the crank pin and they should occur with uniform regularity.

In case of a broken rocker arm link block pin or valve rod it is only necessary to remove the broken parts, place the main valve centrally on its seat and fasten it securely in that position.

A transmission bar, which is really an extension leading from the link block to the valve rod or rocker arm, is applied to make a suitable connection between these two points. The end of this bar, close to the link block is fastened to what is called a transmission bar hanger, to support the transmission bar at that point. If the transmission bar hanger should break, locate the link block in such a position in the link as will provide for handling the train, placing a block in the link above and below the link block to hold the link block in the desired position; securely fastening the blocks to prevent their falling out. It may be possible to use a switch chain to support the transmission bar in place of the broken hanger. If the weight of the transmission bar is not sufficient to prevent its slipping up as the valve moves, a block may be placed between the transmission bar and the point of support inside the chain, so that it will swing with the chain and hold the transmission bar in position. If the transmission bar is broken between the link block and the valve rod or rocker arm connection, place the valve centrally on its seat, fasten it securely, remove the broken parts where necessary and proceed.

BROKEN VALVE YOKE OR STEM

In the event of a valve yoke or valve stem being broken, either with the ordinary slide valve or with the piston valve, if the crank pin is placed on either quarter and the reverse lever is moved from full forward to backward gear, with the throttle open slightly and the cylinder cocks open, steam will show only at one cylinder cock; while if the valve yoke or stem is intact steam will show alternately at each end of the cylinder as the lever is moved back and forth.

If the valve stem is broken inside the steam chest or the yoke is broken, remove the plug from the relief valve opening, push the valve back until it is on center, then fit a piece of wood which will drive into the relief valve pipe and which will just reach to the valve on center and screw the plug and pipe back in place. Then push the valve stem at opposite end solid against the valve and clamp it. This will hold the valve on center.

BROKEN ECCENTRIC STRAP OR ROD, REVERSE SHAFT ARM OR REACH ROD

In case of a broken go-ahead eccentric, eccentric strap or blade, take down the broken part, disconnect the link hanger, allowing the link to drop down on the link block. Disconnect the valve stem and place the valve in a central position, block the rocker arm so that it will not interfere with the valve rod and proceed on one side with the back-up eccentric and blade connected. For a broken backup eccentric, eccentric strap or blade, take down the broken part, disconnect the link hanger, allowing the link to rest on the block or on a bunch of waste inserted between the link and block, tie the bottom of the link so it will not turn over and proceed on both sides. Do not attempt to reverse the locomotive under these conditions as the disabled part will be working in full gear ahead.

If the valve is clamped on center, the cylinder cocks should be removed or blocked open, also remove the indicator plugs in the side of the cylinder castings so that oil may be applied to the cylinders and to relieve the compression to prevent the cylinders from becoming hot. If some provision is not made to lubricate the cylinders and prevent the churning of air back and forth without cool air being admitted, the cylinder may be very badly damaged.

If the reach rod, connecting the reverse lever to the reverse shaft arm is broken, put a short block in the top of one link, and a long one underneath the link block, securely fastening them in position so that the locomotive will work nearly full stroke. Do not block both links. The link blocks are held practically stationary at their support by the link block pins and as the eccentric rods move back and forth they carry with them the top and bottom of the link. The position of the eccentrics on the axle is such that when the crank pin is on one center the eccentrics are in the front of the axle, and when on the other center they are behind the axle, therefore the entire link is movd back and forth even though the reverse lever be in its central position in its quadrant. The link is supported by the reverse shaft arms and link hanger, the latter connecting between the link saddle and the reverse shaft arm. The link saddle is fastened rigidly to the center of the link, therefore as the link hanger swings back and forth with the link, the link is raised and lowered slightly so that the link block must slip a very little in its slot. By holding up the reverse shaft arms the blocking placed in one link will hold up the link on the other side and the necessary slip of the link blocks will be provided for.

PRECAUTIONS TO BE TAKEN WHEN VALVE IS PLACED ON CENTER

Whenever it becomes necessary to place a locomotive on one side, if the main rod is not taken down, the cylinder cocks must be removed or blocked open and the indicator plugs must be removed from the side of cylinder casting, so that oil may be applied to cylinder and to relieve compression.

If some provision is not made to do this the churning of the air back and forth, without admitting cool air, will cause the cylinder to become overheated and damaged.

This applies to both Stephenson and Walschaert valve gears.

BREAK-DOWNS—WALSCHAERT VALVE GEAR BROKEN ECCENTRIC ROD OR CRANK

If the eccentric rod or crank should break, remove the broken parts, disconnect the radius bar hanger from the reverse shaft arm, block the link block in the center of the link. The combination lever will then move the valve the amount of the lap and lead, and will admit steam at both ends of the cylinder at the proper time, but only in proportion as the lead of the valve provides for. This will assist in moving the locomotive and lubricating the cylinder. See that the radius bar is blocked substantially so that the link block cannot move from its position in the center of the link.

If it is impracticable to block the link block in this manner disconnect the combination lever, move it forward against the back cylinder head and tie it securely in that position. See that the crosshead and all of its parts clear the combination lever throughout its movement in the guides. Disconnect the reverse shaft arm from the radius bar, allow the link block to drop to the bottom of the link. Then place the valve on center and clamp it securely in this position.

BROKEN VALVE STEM, RADIUS BAR OR ROD

In the case of a broken valve stem or rod, if the moving parts attached to the combination lever and the valve rod or stem can be removed so that they will not interfere with the movement of the combination lever, and the combination lever is supported such as might be the case with a crosshead or other guide, it is only necessary to place the valve centrally on its seat and secure it there. If there is no support for the combination lever or if the movement of same would cause it to strike other parts when disconnected, take down the combination lever, disconnect the radius bar from the reverse shaft arm, raise the front end of the radius bar and fasten it to clear other parts. Then take down the eccentic rod and fasten the valve centrally on its seat.

BROKEN RADIUS BAR HANGER, COMBINATION LEVER OR UNION LINK

If the radius bar hanger which holds up the radius bar should break, place a bunch of waste below link block in the link and wrap heavy wire around link block and bottom of link to hold the link block down on the waste. Remove the broken parts that do not clear and proceed.

If the combination lever breaks, take down the radius bar hanger and the eccentric rod, and all other parts supported by them. Place the valve centrally on its seat and fasten it securely, and proceed on one side. If it is possible to connect the radius bar directly to the valve stem or valve rod so that it will provide for moving the valve, this may be done and the locomotive proceed working on both sides.

If the union link connecting the combination lever to the crosshead should break, disconnect the eccentric rod and the radius bar hanger to the reverse shaft; allow the radius bar to ride at the bottom of the link and fasten the combination lever to the cylinder head or remove it, so it will clear the crosshead. Then place the main valve centrally in its seat and fasten it securely in that position and proceed on one side.

BREAK-DOWNS—BAKER VALVE GEAR

Two means are provided for blocking the gear and valve in case of a break down. The valve stem crosshead in some cases is provided with a set screw that may be screwed down tightly to hold the crosshead in the desired position, if the valve stem is fastened to the crosshead so that the crosshead will hold the valve, this means may be used to block the valve in central position. Another way is to bolt the lower arm of the bell crank to the side of the gear frame, if the connections to the valve stem are intact this will hold the valve in place. See that the bell crank arms are blocked so that there will be no movement between the bell crank arm and the bolt. Some of the Baker valve gear frames have two holes drilled in them to provide for this method of blocking. It is possible to use wedges between the bell crank arms and the side of the gear frame in case bolts cannot be used. When the gear is blocked in this manner the following parts may fail without necessitating the removal of the combination lever of its connections:

The eccentric crank or arm, the radius rods, the reverse yoke, the short reach rod and the horizontal arm of the bell crank. Operating the locomotive with the gear blocked in this manner provides for admitting steam to each end of the cylinders by opening the steam port in proportion to the lead, the same as with the Walschaert valve gear.

If the union link or cross head arm connecting the combination lever to the cross-head should break, disconnect the eccentric rod, also the reach rod connecting to the reverse yoke. Fasten the bottom of the combination lever to the cylinder head or remove it and place the valve centrally on its seat, fastening it securely in that position.

In case the combination lever breaks, it will be necessary to take it down and disconnect the valve rod or stem, fastening the valve centrally on its seat. See that all moving parts are either removed or that they are supported or fastened so they will not strike or loosen and do further damage.

If the gear connecting rod should break, disconnect the eccentric rod, then block the bell crank the same as for broken eccentric rod or crank. If the valve rod breaks, clamp the valve centrally on its seat, removing any parts of the gear which are liable to interfere with the locomotive moving.

DISCONNECTING VALVES AND MAIN RODS

With any type of valve gear, if it becomes necessary to block the main valve centrally to its seat, have the crank pins located so that locomotive can be started. For this purpose it is best to move the locomotive until the crank pin on the side not disabled is located slightly back of the top quarter or ahead of the bottom quarter, if the locomotive is to move forward; or the reverse of this if movement is to be made backward. Shift the valve by hand on the disabled side to accomplish this before blocking. This method may be used should the locomotive later stop with the crank pin on center so that it is impossible to start.

In case of a broken valve seat, with slide valves, if the break occurs between the steam admission port and the exhaust port, and the loss of steam is such that it is impossible to maintain steam pressure and handle train; if the valve is not damaged disconnect the valve rod, place the valve centrally on its seat, operating the locomotive on one side. In such cases it may be determined whether the blow can be stopped by placing the valve centrally on its seat by simply placing the crank pin on either the top or bottom quarter and the reverse lever in the center, giving the locomotive steam. If the seat is broken so badly that steam will blow through in any position of the valve, and the loss of steam is such that the locomotive cannot be operated without stopping the blow, take up the steam chest cover and plug the live steam ports, placing blocking on top of these plugs and bolting the blocking down solid by bolting the steam chest cover on top of the blocking. Of course, it will be necessary to remove the valve in order to accomplish this. If this cannot be done, disconnect the valve rod and have locomotive towed in.

In the case of broken bushing, with piston valves, if the blow is so heavy that the locomotive cannot be operated, place the valve centrally on its seat and if this will stop the blow disconnect the valve rod, fasten the valve securely and proceed.

If the blow cannot be stopped by placing the valve centrally on its seat, and is so heavy that the locomotive cannot be run light, it will be necessary to disconnect the valve stem on that side to avoid possibility of damage from the broken parts and arrange to be towed in. Usually if the bushing is so badly broken that the loss of steam at the exhaust is so heavy that the locomotive cannot be run light, the valve or some part of the valve gear is also damaged.

If necessary to disconnect a locomotive on both sides, so that the locomotive must be towed in, disconnect only those parts necessary to provide for the locomotive being moved, remove the indicator plugs to provide lubricating the cylinders if necessary. If it is not necessary to disconnect either valve rods or main rods, the cylinders may be lubricated by disconnecting the oil pipes near the steam chests, or the choke valves may be removed from the oil pipes, and the cylinder lubricated by using the auxiliary oil cups on the lubricator. If steam can be passed through the oil pipes in the usual manner, the cylinders may be lubricated by operating the lubricator.

In each case where the valve rod is disconnected and the valve is placed centrally on its seat, it should be securely fastened in that position. If the main rod is not taken down the indicator plugs should be removed to provide for lubricating the cylinder and relieving compression.

BLOCKING MAIN VALVE ON CENTER

To hold the valve centrally on its seat when it is desired to operate the locomotive on one side, the valve stem may be fastened by loosening the packing gland nuts and prying one side of the gland away from its bearing, then apply a small wedge on that side behind the gland and tighten the nuts on the opposite side. The balance of the nuts should be drawn up tight enough to prevent their working off. Be careful not to cramp the gland so tight on the valve stem that it will be cracked or broken. If the valve stem is fitted into a crosshead and the stem is not broken, block the crosshead to hold the valve. Locomotives are equipped with clamps for clamping the valve stem. The valve may be held by blocking the valve rod, using wedges between the valve rod and frame or any nearby castings or other parts if the valve rod and valve stem are connected after disconnecting other parts.

BLOCKING CROSSHEAD AND CRANK PINS

Do not neglect in any case, when the main rod is disconnected, to firmly block the crosshead at the front of its guides, unless conditions make this impossible. Steam may leak into the cylinder, and if the crosshead is not firmly blocked, the piston may be moved, resulting in considerable damage. Remove the indicator plugs at the front end of the cylinder or take out the front cylinder cock. If the crosshead is blocked at the back end of guides, take out the cylinder cock or indicator plug at that end of cylinder and make sure that front crank pin will not strike crosshead.

In any case where the main rod is taken down and side rods remain in place, see that blocks provided for that purpose are clamped on the main pin to hold the side rod in place. Locomotives equipped with main rods having floating bushings can be blocked by removing floating bushing from main rod, and apply it to the main crank pin instead of using wooden block.

PISTONS, PISTON RODS AND CYLINDER HEADS

In case of piston rod breaking near piston, remove the piston head and clamp the valve on center. If piston rod is broken near crosshead, remove the piston and rod and clamp the valve on center. In case follower bolts work loose and become bent so that they cannot be tightened, or in case of broken follower plate, remove the front cylinder head and block the valve on center.

If the front cylinder head has been blown out or broken, block the valve centrally on its seat. Proceed with as much tonnage as the locomotive is capable of handling.

CRACKED OR BROKEN STEAM CHEST OR VALVE CHAMBER HEAD

In the case of a cracked slide valve steam chest, slack off on the steam chest studs and wedge between the wall of the steam chest and studs to force the cracked sides together, then tighten down on the cap studs.

If a steam chest is broken so that it cannot be wedged in place sufficiently, block the same as explained for a broken valve seat for slide valves.

If a valve chamber head of a piston valve locomotive is cracked, the loss of steam may be considerably lessened by chaining around the valve chamber and wedging tightly between the chain and valve chamber head to hold the damaged parts together, or use a small jack in place of wedges under the chain.

When a locomotive is reversed air pressure in the cylinders is forced into the valve chambers and steam pipes up to the throttle valve. The piston in the cylinder will draw air into the cylinder through the cylinder cocks and exhaust and on its return stroke will compress this air, driving in through the valve chamber. Consequently, if a locomotive is moving at a good speed and the valve motion is reversed, the cylinders will build up a heavy pressure in the steam chests and valve chambers, and unless the throttle is opened, may create a sufficient pressure to damage the steam chest or connections leading back to the boiler. At high speeds some of these parts are usually damaged unless the throttle is open.

When for any reason, any part of the valve gear is disconnected so that the valve motion on both sides of the locomotive cannot be reversed together, no attempt should be made to reverse the locomotive without first stopping and changing the blocking on the disabled side, so that both sides of the locomotive will work in unison.

KEYING UP MAIN AND SIDE RODS

When keying up the back end of the main rod, place the crank pin on the lower back eighth. Usually the main rod brasses are so fitted that they may be keyed up brass to brass without danger of being too tight on the crank pin. In any case, when keying up rod brasses, it should be determined that the brass has not been keyed up too tight, by moving the rod from side to side on its crank pin.

In keying up the brass at the front end of the main rod, the crank pin should be placed on the bottom quarter.

In keying up side rods, the crank pin should be placed on the front or back center, in order that during the process of keying up the rods, the proper length of rods will be maintained. If the crank pins are near the top or bottom quarter when the side rods are keyed up, the rods may be keyed to an improper length, so that as the crank pins pass the center there will be a tendency to force the driving wheels against their bearings. This would set up damaging stresses throughout the rods, crank pins, driving axles and frames.

In case a side rod key is lost, endeavor to fill up the key-way with a piece of iron of any suitable size, or if possible, wedge several pieces into the key-way. A number of brake shoe keys removed from a car or the tender may be used driving them down firmly and if possible bending them over at the bottom to prevent their coming out. The brake on the tender or car from which the brake shoe keys were removed, should have the brake shoes removed and the brake cut out, making sure that safety hangers are in place and in condition to hold up the brake beam in case the regular hanger slips out of its slot.

BROKEN GUIDES, YOKE, BOLTS OR BLOCKS

In case of broken guide bolts, if other parts are not broken or distorted, see if a bolt can be secured from some part of the locomotive or a car to use temporarily to get locomotive to terminal.

If a guide block is broken, or the guides are broken or badly sprung, if the crosshead is broken, or the guide yoke is broken, take down the main rod, also disconnect the valve rod and place the valve centrally on its seat. If the crosshead can be moved to the other end of its guides, it should be blocked at one end of the stroke, preferably the front end. If the crosshead cannot be blocked at either end of the stroke, it should be blocked securely on both sides to hold it in whatever position it happens to be. When blocking the crosshead in its guides on any locomotive, see that the front crank pin will clear the crosshead.

BROKEN SPRINGS, HANGERS AND EQUALIZERS

In the case of a broken cross equalizer in front of the front driving boxes, if the locomotive is equipped with a two wheel truck in front, which is connected to a long equalizer reaching under the saddles, raise the locomotive as high as possible by running the engine truck wheels upon wedges, then block between the top of the front driving boxes and the main frame, see that the main frame clears the engine truck frames to provide for the proper curving of the truck, also that the lowest part of the driving brake gear is high enough to clear rails, switches, etc. Raise the back end of the long equalizer if necessary and block it up to clear rails, etc.

If the long equalizer connecting to the front truck and leading back under the cylinder saddles breaks, raise the locomotive as high as possible by running the engine truck wheels upon wedges, placing a metal block between the top of the front driving boxes and the frame, block between the back edge of the cylinder saddles and the top of the long equalizer, if the break occurs be-

tween the saddles and engine truck. Then remove the wedges. If the locomotive is high enough so that the main frame clears the engine truck frame and the driving brake parts are high enough to clear the rails, frogs and switches, the locomotive may proceed. If it is necessary to raise the locomotive higher, place the wedges under the front driving wheels, raise the locomotive as high as possible through this means, block between the top of the engine truck and the main frames or casting; remove the wedges and run the engine truck wheels on the wedges again, placing additional blocking between the back edges of the cylinder saddles and the long equalizers, then remove the wedges. It might be necessary to place blocks between the top of the driving box and the frame at the second pair of drivers, then running that pair of wheels upon the wedges and blocking between the top of the front driving boxes and the frames, in order to support the locomotive high enough in front to clear the engine truck and provide for curving. Run slow enough when blocked up in this manner to prevent overheating bearings or damaging main frames or journals.

If the long equalizer breaks behind the cylinder saddles, raise the locomotive in front by raising the truck wheels upon wedges and blocking between the top of the front driving boxes and the frames. This method should also be used in case the hanger at back end of the long equalizer breaks.

In the case of broken driving springs, block the equalizers each side of the broken spring so as to hold them in as nearly their normal position as possible, removing or fastening the broken spring if necessary before proceeding.

In the case of a broken driving spring equalizer proceed the same as for a broken spring hanger or spring, blocking all parts closest the break in as near their normal position as possible.

In the case of a broken driving spring or hanger or broken driving spring equalizer, or engine truck equalizer which connects the driving springs to the engine truck; note if all spring hangers and other parts are tight and in their supports, so there is no danger of any of the parts falling out of place while the locomotive is moving. If necessary secure the broken parts so that they will remain in position. If no parts interfere when the locomotive is moved a few revolutions the locomotive may proceed. Before proceeding note whether the lower parts of the driving brake rigging and also any broken parts are high enough to properly pass over rails, switches, etc. Also see that the main frame and other parts clear the engine truck frame in order to provide for the proper curving of the truck. Remember that the weight is not properly equalized on the driving wheels and truck wheels, and there is therefore liability of some bearing overheating. Run slowly when proceeding in this manner so as to prevent badly overheating bearings or damaging main frames, journals or rails, as the weight will be excessive on those wheels required to carry the weight on account of the broken parts. If necessary to raise the locomotive, place metal blocks between the driving boxes and frame which have the most clearance between the driving boxes and frame, and which are nearest to the broken spring or hanger. Then run the driving wheel upon a wedge to raise the locomotive frame, raising the locomotive as high as possible, block the spring equalizers closest to the point of breakage, as nearly to their normal position as possible. If the reverse lever can not be moved, take out the pin connecting the reach rod to the reverse shaft arm, blocking in the top of one link above the link block, and in the bottom of the same link under the link block, setting the link block at a position in the link which will provide for starting or it might be possible to place a bar across the frame, under the reverse shaft arms to hold the links in the desired position. Secure the bar to the frame and also to the reverse shaft arms, so that they will remain in that position.

If an engine truck spring or spring hanger breaks, with a four-wheel truck, raise the truck frame and block between the bottom of truck frame and the equalizers, to hold the truck frame in its normal position.

If a trailer truck equalizer or spring is broken, examine the broken parts to determine whether or not they will interfere in any way when the locomotive is running, and also whether there is liability of any of the parts falling out of place while the locomotive is moving. If not, proceed; remembering that the weight is not properly distributed on all bearings and that overheating of the truck and driving boxes may occur.

On trailer trucks having outside journals, when a spring or spring hanger or equalizer breaks, the truck will be tilted up on the broken side on account of the weight being relieved. This may cause the truck to be derailed in backing up. In case of breakage of the above parts, raise the locomotive frame at the rear and block between the trailer radius bar or other part of trailer truck frame and the main frame. A convenient place to do this is at the corner of the truck frame where the radius bar is bolted to truck frame, the blocking to be placed between the truck frame and the bracket or guide bolted to main frame. The guide or bracket loops around the trailer spring seat, and bolts to the main frame at both ends. The object of blocking up as described, is to hold trailer wheel solid on the rail. The back end of the frames may be raised by running the back driving wheel upon a wedge.

When blocking up between the trailer and main frame as described, see that all parts of the trailer truck frame and main frame clear the trailer truck axle. If necessary run the trailer wheels upon a wedge and block on top of the back driving box on the disabled side, then run the wheel off the wedge, jack up the back end of the trailer equalizer and block between the top end of the equalizer and the main frame forward of the fulcrum pin. If the trailer axle clears the main frame sufficiently the locomotive may then proceed. If necessary to support the locomotive at other points to insure the frame clearing the axle, run the trailer wheels upon a wedge then block between the top of the draw-bar between the engine and tender and tail

brace, as close as possible to the chafing iron. Metal blocks should be used for this purpose and they should be secured so they will not fall out of place. Run the trailer wheels off the wedge. If the main frame clears the axle the locomotive may then proceed at reduced speed.

BROKEN MAIN ROD, SIDE ROD OR CRANK PIN

If a main crank pin is broken off, all side rods on both sides of the locomotive and the main rod on the disabled side should be taken down. The crosshead on the disabled side should be properly blocked at the front of its guides, if it will clear in that position the valve rod disconnected and the valve placed centrally upon its seat and securely fastened there. The locomotive should be handled carefully under these conditions as any attempt to move the locomotive suddenly results in violent slipping of the driving wheels on account of the full power of the cylinder being exerted on only one pair of driving wheels.

In the case of a broken main rod or strap, take down the broken main rod on the disabled side, place the valve centrally on its seat and securely fasten it there. Securely block the crosshead at the front of the guides if it will clear in that position and proceed on one side. To hold side rods in place, either apply wooden blocks, which are provided for this purpose, or use the floating bushing from main rod.

On certain classes of locomotives front crank pins will not clear crossheads when rods are disconnected unless crosshead is blocked at forward end of its travel. These classes are: 1798, 3160, 3800, 5000, 4000, 4101.

When main rods are removed from locomotives of these classes the crossheads must be securely blocked in position where front crank pins cannot strike them. Locomotives of these classes that are moved, either dead or under steam, with one or both main rods in place, and front side rods removed, must have front driving wheel swung clear of rail, and blocked so as to hold front crank pin in position where the crosshead cannot strike them.

If a side rod breaks, remove the same section of the side rods on the opposite side. In some cases it will be necessary on account of knuckle joints, to remove an additional section besides the broken sections of rods, in which case corresponding rods on the opposite side should also be taken down. When side rods are removed care must be used in handling the throttle valve as slipping of the driving wheels occurs very easily.

BROKEN WHEELS AND AXLES

If an engine truck, trailer, or tender wheel breaks, endeavor to slide that pair of wheels so as to clear the main line, placing a tie or its equivalent in front of the wheels or chain the wheels to keep them from turning if necessary.

If an engine truck, driving axle, trailer or tender axle breaks, it is usually impossible to do anything, except send for help. However, in the case of small locomotives, if it is a back engine truck axle, the back end of the truck frame may be jacked up and blocking placed between the front end of the truck frame and the main frames. A chain may then be placed around the back end of the truck until the locomotive can be gotten clear of the main line. If a front engine truck axle is broken, endeavor to raise the front end of the truck high enough to clear, block between the main frames and the back end of the truck frame, chaining the front end of the truck frame to the main frames.

With a broken tender axle on rear end of rear truck, endeavor to raise that end of the truck and chain it over the rear end sill. If it is either of the inside axles, place a tie or rail or other timber if available, across the top of the tender, chaining up each side to support that end of the truck. If this is impractical endeavor to jack up the broken end of the truck frame, so that a tie may be placed under the truck frame on the rail, so that the locomotive might be moved to a point where the main line will be cleared. If a front axle on the front tender truck breaks, chain the truck frame to the front end sill. It is possible on some of the steel underframe tenders to place a piece of rail or other suitable support between the bottom of the tender and over the plate just above the tender truck, so that the end of such rail or timber will protrude over the tender journal box for chaining up the inside ends of front or back trucks.

With an eight wheel locomotive, if the back driving tire is broken, run the back wheel with broken tire upon a wedge to raise it clear of the rail, remove the driving box cellar and place a block between the driving spring saddle and the frame at the disabled wheel, also place a block between the driving axle and the binder brace or pedestal to fill the space tightly under the journal having the wheel raised. If, when the wheel is run off the wedge, there is not sufficient clearance to prevent the wheel touching the rail, try again raising the locomotive and place a tie on the tank and engine deck, chaining around the tie and the back end of the engine frame or tail brace, to support some of the weight of the back end of the locomotive on the tender. At the same time chain from the back end of the locomotive frame on the side of the broken tire, to the front end of the tender frame on the opposite side, to hold the flange of the back driving wheel against the rail. Blocking on top of the main driving box on the disabled side and the back driving box on the opposite side will help to support the rear end of the locomotive and may avoid the necessity for carrying any weight on the tender deck. Blocking may be used between the end sill on the tender and the engine deck at the outside end of end sill on the opposite side from damaged wheel, to prevent that side of locomotive moving over and causing derailment. Chain or fasten the blocking so it will not fall out of place.

If other than the back tire of an eight wheel locomotive is broken, run that wheel upon a wedge, remove the driving box

cellar and block solidly between the spring saddle and main frame over the wheel with broken tire, also block solidly between the driving axle and the pedestal or binder brace so that the wheel will be held clear of the rail when the wedge is removed. If the broken tire comes off the wheel and the distance to clear the main line is not far, the locomotive may be moved to clear by running on the wheel center. If other trains will not be delayed block up at once. It may be necessary in the case of the back tire on other than eight wheel locomotives, to block on top of the driving box at the next pair of wheels, using a metal block between the top of the box and the frame to help support the back end of the locomotive to keep the back wheels clear of the rails after blocking them up.

If a driving axle breaks between the frames it may be possible to handle the locomotive carefully for a sufficient distance to clear the main line without the necessity for blocking up in any manner. If the driving wheels stand approximately in their normal position this may be attempted, being careful not to slip the driving wheels, and proceeding slowly. If they stand in such a position that the side rods are badly cramped, remove the side rods, moving the locomotive sufficiently to loosen the side rods if possible, run the wheels at the broken axle upon a wedge, and if necessary jack up the end of the axle between the frames so that the driving box cellars may be removed, place a block solidly between the driving axle and the pedestal brace, chain the bottom of the wheels together tightly, or place a timber or rail through the driving wheel spokes and over the top of the frames to help carry the weight of the wheels. When the wheels are removed from the wedges they could clear the rails.

If the main axle breaks outside the driving box, remove all the side rods and the driving wheel, jack up the broken end to normal position, remove the driving box cellar and block solidly between the axle and the pedestal brace; also block solidly between the spring saddle and the frame at the point where the axle is broken.

When locomotives are being prepared for towing on account of being disabled, the engineer must consider the necessity for cutting out the driver, tender or trailer brakes. If there are no defects which would make it unsafe to operate the brakes they must be left cut in and working.

Locomotives handled dead in trains with side rods in position are not to be run faster than 20 miles per hour.

Locomotives with side rods all removed, and all drivers are on the rail, may be handled at a speed of fifteen miles per hour or one mile in four minutes.

Where tire is broken, or an axle is broken, necessitating the swinging of one or more pair of wheels, the speed should not exceed one mile in six minutes.

When wheels are blocked up to clear the rail, the weight formerly carried by such wheels must be transferred to other wheels. This causes the weight to be excessive on the wheels which are required to carry the additional weight, making the weight excessive beyond a safe limit for high speeds.

In all cases of break-downs where blocking or chains are used to support the weight in place of springs or hangers, or if the wheels are blocked up, the locomotive should be moved slowly and carefully to avoid derailment, particularly in case chains or blocking should fail. The speed should be kept very low and care used in passing over frogs and switches to prevent derailment at such points.

After jacking up a locomotive or running wheels up on wedges for the purpose of blocking up, see that the waste under the engine truck or trailer journals, and that driving box grease cellars are properly adjusted, or if oil cellars are used for the driving boxes, see that the waste is properly adjusted. If the locomotive has been off the truck, inspect all the cellars under the locomotive to see that cellar bolts have not been broken or that the waste has been pushed down so as to clear the journals, making such adjustments as are found necessary. The plates in grease cellars may be pushed down and distorted or stick under these conditions. These precautions are necessary to guard against hot boxes due to the weight of axles and wheels being sometimes carried on the cellars during rerailing locomotive after derailment.

In all cases of wheels, axles, tires, springs, equalizers, etc., breaking and where weight has been transferred to other wheels, and repairs are made which will enable the locomotive to proceed light or with a train the locomotive may be moved slowly to the first telegraph office where instructions must be obtained whether or not to proceed on to terminal.

POUNDS

If any of the following defects exist, pounds will occur when the locomotive is working: Piston head loose on the piston rod, follower plate bolts loose, piston rod loose in the crosshead, main rod too long or too short, wrist pin loose in the crosshead, rod brasses loose on crank pins or not properly keyed, pedestal brace or binder loose, driving axle worn out of round, crosshead loose in its guides, knuckle pins or their bushings in side rods worn.

The follower head loose or the main rod too long or too short will pound most when the locomotive is drifting with the throttle closed, because the weight of the moving parts will take up all the slack in the connections and may cause the piston to strike the cylinder head. If the main rod is too short the piston will strike the back cylinder head. If the main rod is too long the piston will strike the front cylinder head. If a pound occurs when the throttle is closed in drifting, open the throttle and work sufficient steam to cushion the moving parts until a stop is made.

The piston rod loose in the crosshead will pound the hardest when the locomotive is working steam. The piston rod is taper fitted at the piston head and also has a taper fit into the crosshead. When steam is admitted behind the piston head it tends to pull the piston rod out of the crosshead and drive the piston head off its rod, while on the other hand, if steam is admitted in front of the piston, the piston head is driven back on the taper fit and the piston rod is driven into the taper fit in the crosshead. The heaviest pound would therefore take place when the piston was being driven forward in its cylinder.

When there is lost motion between the driving box and shoes it allows the driving box to move back and forth when power is applied at the crank pin, causing very heavy pounding to take place, and to determine how much lost motion exists, the crank pin should be placed on the top or bottom quarter on the side being inspected, have the fireman open the throttle a very little and move the reverse lever from the forward to the backward position several times, noting the movement of the driving box at this time. Care should be taken not to let the locomotive move so that the crank pin will be moved from its position on the quarter. The driving brakes should not be applied at this time, they should, however, be operative, so that the locomotive may be stopped promptly in case it starts to move. Sometimes it is difficult to reverse a locomotive with the throttle open, try opening the cylinder cocks to assist in such cases. It might be possible that a heavy pound will be noticed that is not caused by improper adjustment of the wedge. Such pounds may occur on account of a loose or broken binder or pedestal brace, or the driving shoe or wedge may be improperly lined, that is, it may be tight at the top or bottom and loose at the other end. The journal or driving box brass may be badly worn or broken. If the driving box wedge has been moved up as far as it will go, or until it strikes the frame and still the box pounds, the wedge should be reported for relining.

The same method of placing the crank pin on the quarter and reversing the locomotive under a light throttle should be used to locate pounds in the main or side rods.

MAIN THROTTLE VALVE LEAKING OR DISCONNECTED

If, when the throttle is closed, steam shows at cylinder cocks, it may be caused by a leaky throttle, leaky dry pipe or from the chokes of the hydrostatic lubricator being badly worn. To determine where the leak exists, close the steam valve to the lubricator and shut off the air pump. If this stops the blow at cylinder cocks the trouble is in the lubricator chokes. If the blow does not stop, fill the boiler with water so that it will be high enough to cover the dry pipe and open the cylinder cocks. If dry steam shows at cylinder cocks under these conditions the throttle is leaking. If both steam and water show at cylinder cocks it would indicate the dry pipe leaking.

If the main throttle becomes disconnected and the throttle valve is closed, prepare the locomotive to be towed to terminal, or to some point where repairs can be made. If the locomotive was located at a point where relief was not available, and facilities were at hand the boiler may be filled up well with water, the steam blown off, allowing the boiler to cool down, the dome cap removed and the throttle connected up.

If the throttle becomes disconnected open, it requires great care in order to handle the locomotive. The steam pressure should be reduced low enough so that the locomotive may be handled with the reverse lever and brakes.

LOCATING BLOWS IN VALVES AND CYLINDERS

If anything occurs which would allow live steam to pass by the ends of a piston valve to the exhaust port, or by the face of a slide valve to the same port, there would be a constant blow at the exhaust. On the other hand, if the valve is tight and the steam piston allows the steam to pass from one end of the cylinder to the other, a blow will occur only while steam is being admitted to either end of the cylinder.

To test for blows in valves with simple locomotive, place crank pin on top or bottom quarter, reverse lever on center, apply brakes, open cylinder cocks and then open throttle. If steam appears at cylinder cocks the valve or rings are leaking.

To test for blows in cylinder packing, with simple locomotive, place crank pin on top back eighth or bottom forward eighth, reverse lever in full forward gear, apply brakes. Now pry open front cylinder cock with a round bar or other means to determine if steam blows through to the front end of the cylinder. If there is no blow by the piston, little or no steam will show at the front cylinder cock.

The exhaust rings in a piston valve will cause blows to occur as the exhaust ring is moving back and forth over the bridges between the steam and exhaust ports. They are difficult to locate when the locomotive is standing unless the valve is moved to certain position off center or off its central position on the seat. When the crank pin is on the top or bottom quarter and the valve is placed in its central position, the admission rings prevent steam entering the cylinders. Moving the reverse lever slightly toward either end of its quadrant moves the valve away from its central position and places the exhaust ring on the bridge between the admission and exhaust ports. A blow may occur at the stack at this time and steam show only at one cylinder cock. This would indicate that the valve was causing the blow at the stack and not the cylinder packing.

With balanced slide valves, if the strips are leaking, either where they seat against the balance plate or in the grooves cut in the valve body, or if the strips leak where they join at their ends, steam will be admitted to the top face of the valve, since there is a hole through the top of the valve connected to the exhaust a blow will occur at the stack, with the valve in any position on its seat. With the valve in its central position on the seat no steam may show at the cylinder cocks when this

blow occurs. On the other hand, opening the cylinder cocks may show that air is being drawn into the cylinder. If the locomotive is equipped with channel cocks, located underneath the saddles and connected to the exhaust channels leading to the nozzle, opening the channel cocks will show on which side the valve is blowing to the exhaust.

Sometimes steam may be admitted to one end of a cylinder which will cause a blow at both cylinder cocks and at the stack, while admitting steam to the other end of the cylinder will show steam only at the cylinder cock on that end, with no blow at the stack. This might be caused by the follower plate on the piston being loose, and when the steam is admitted to one end of the cylinder the follower plate is blown loose from its joint letting the steam blow by the piston, while when the steam is admitted to that side of the piston on which the follower plate is located, the follower plate is blown tightly to its seat, which, of course, prevents the blow in that direction.

HOT BEARINGS

Two surfaces in contact under motion create friction, which develops heat. The introduction of a lubricant, such as oil, between these surfaces keeps them separated, reduces the friction and this reduces the heating. In the case of a hot bearing, it should be determined if the surfaces are overheating due merely to lack of lubrication, or whether it is because the two surfaces are drawn together so tightly that it is impossible to get any lubricant between them. If the parts are so arranged that there is some clearance it may be only necessary to introduce proper lubricant to overcome the heating, unless the surfaces are badly cut. It might be possible in the case of eccentric straps or guides to loosen the bolts holding such parts together to provide sufficient clearance, applying shims or liners to keep them separated, and tighten the bolts securely. In a case of rod brass heating, if key is provided, it should be slacked off, if it is found that the brass fits the pin tightly. Remember that when heating takes place, the various parts expand, which may be responsible for the parts being found excessively tight when hot bearings occur.

In case of hot journals, such as driving boxes, engine trucks or trailers, determine if the journal inside the frames shows the same or greater heat than the outside of the hub. If the wheel hub and end of axle is considerably hotter than the axle inside the frames close to the box, and there is not much indication of heat in the box itself, it is evident that the heat is being generated in the wheel hub. If allowed to continue this may cause sufficient heat throughout the journal to thin the oil and cause the box to run hot, unless the hub receives sufficient lubrication to prevent this. Examine for lateral motion at both wheels, to determine if there is any clearance between the wheel hub and the box on either side. If the boxes fit closely against the hubs on both sides continued care will have to be given the hubs on both wheels. When oiling the hub under these conditions, the box should also be thoroughly oiled. Examine to see if the cellar is properly in place. The box should be inspected at every opportunity to determine whether or not the heat is increasing or decreasing. If it is found that the heat increases, and the packing burns or smokes, or the grease has melted out, the cellar should be repacked at once, that is, the locomotive should be run no great distance after discovering this condition. If possible pick out a place to stop where the train can be started readily.

When a bearing is discovered to be unusually hot, that is, the metal is at a very high temperature or nearly red hot, care should be taken not to cool the bearing suddenly. The temperature should be reduced sufficiently, or to a point where engine oil will not flash or burn. The cellar should then be repacked.

Where hot bearings occur and there is liability of causing excessive delay to a train, it should first be learned whether another locomotive is readily available to take the train. Where the conditions are such that a reduction in speed will enable the train to reach its terminal, or some point where relief might be had, without incurring any greater delay than would be caused by waiting for relief, such relief should not be requested.

Ordinarily, journals, or other bearings lubricated with what is commonly called pin grease, or driving box grease, run considerably warmer than bearings lubricated with oil, and this must be taken into consideration when inspecting the various bearings throughout the locomotive. If a bearing, lubricated with pin grease, or driving box grease, gets excessively hot, it should be known that the bearing is receiving proper lubrication. If necessary refill the cups or cellars to provide for this. In the case of driving boxes it should be known that the driving box wedge is not stuck, that there is grease in the cellar, that the plate is not stuck and that grease is up against journal. If it is impossible to repack grease cellars, oil the hub side of the driving box liberally with valve oil, and also apply valve oil to the cellar from the inside, if possible. If no grease is available it is sometimes possible to place ordinary packing thoroughly saturated with valve oil on top of the perforated plate in order to get locomotive to a terminal without cutting journal.

To pack a grease lubricated driving box, remove split key from end of inside cellar bolt, withdraw inside cellar bolt far enough to allow removal of end plate. Then remove end plate, pull down the follower, or spring plate, by inserting packing hook or small bar through the loops of the indicator wires or tell tales, and pull spring plate down and block in that position. If a formed grease cake is available, remove the old cake and the perforated plate, clean out cellar, and apply new cake.

At all servicing points and at many intermediate points, prepared grease cakes with perforated plates in place, are available for emergency use.

If no new grease cake is available, see that old cake and perforated plate are free to move in cellar, and place pin grease

on top of perforated plate, full length of plate. Release follower plate and see that it holds the new grease firmly against the journal. Reapply end plate, and replace cellar bolt and split key.

When trouble is experienced with a hot driving box that is lubricated with grease, do not depend upon the indicator wires or tell tales. Make sure that the follower plate and grease cake are free in the cellar, that there is sufficient grease in the cellar and that cake is held firmly up against the journal.

The use of water should be resorted to only after all other methods have been employed. With driving boxes, engine trucks, and trailers of the inside type the Keeley's should be adjusted to permit water to flow between the hub and the box, not on top of the box, as all of the lubricants will be washed from the journal packing. When water is used in the journal box on a tank truck, or outside trailers, it should be used continually, until the box is again packed with oiled packing. The engineman should make frequent inspections to know that the packing in the cellar is up to the journal, as should the packing recede and the water flow out of the box by the dust guard, there is a liability of burning off the journal, even though the Keeley is running a full stream. When applying Keeley to a tank box, or outside trailer, be sure that packing is up against the journal, and that packing is set up in the back of box to prevent the water running out, without coming in contact with the journal.

MOVEMENT OF DEAD OR DEFECTIVE LOCOMOTIVES

Locomotives which are disabled, due to failure on road, may be moved dead, at a speed of not more than 10 miles per hour, with main rods, crossheads and pistons (all moving parts except valve gear) connected; it being understood that a locomotive in this condition may be moved to, but not beyond, the nearest point in the desired direction at which locomotive maintenance forces are employed. The cylinders of locomotives moved in this condition are to be lubricated at intervals of not more than 15 miles with one-eighth pint of valve oil introduced through each indicator connection on right and left cylinders.

If it is necessary to remove a side rod account of defective condition of locomotive such as broken side rod, broken crank pin or broken axle the corresponding side rod on opposite side of locomotive must also be removed. If a main connection side rod of the knuckle joint type has to be removed all other side rods on the locomotive must also be removed.

If a side rod of the knuckle joint type between third and fourth pairs of drivers has to be removed from a locomotive having five pairs of drivers both back side rods of the locomotive must be removed in addition to the corresponding side rod on the opposite side.

On certain classes of locomotives, front crank pins will not clear crossheads when rods are disconnected unless the crosshead is blocked at forward end of its travel. These classes are: 1798, 3800, 4101, 5001, 3160, 4000, 5000.

When main rods are removed from locomotives of these classes, the crossheads must be securely blocked in position where front crank pins cannot strike them. Locomotives of these classes that are moved either dead or under steam with one or both main rods in place and front side rods removed, must have front driving wheels swung clear of rail and blocked so as to hold front crank pins in positions where crossheads cannot strike them.

Before being moved dead in train, a locomotive with a broken driving axle, broken driving wheel center, or driving tire broken or missing, must have damaged pair of wheels jacked up and blocked so that wheels cannot touch the rail.

Broken engine truck, tender truck and trailer truck tires, wheels or axles must be replaced with serviceable spare parts before locomotives are moved dead in train, except that a locomotive on which any one of these parts fails while on the road may be moved at a speed of not more than five miles per hour (one mile in twelve minutes) to the nearest point at which the locomotive may be gotten off the main line and placed on siding where a wrecking crane can be used to remove defective, and apply replacement, parts.

Locomotives equipped with main rods of the tandem type are not to be moved or operated with one main rod removed. Other locomotives operating under their own steam with all side rods in place and one main rod removed must not be operated to exceed the following speeds:

MILES PER HOUR

20	25	35
All Freight and Switch Locomotives.	Passenger Locomotives	
Includes Types:	Mountain Type. Includes Types:	All Locomotives Except Mountain Types. Includes:
0-4-0 2-8-2	4-8-2	4-4-0
0-6-0 2-8-4	4-8-4	4-4-2
0-8-0 2-10-0		4-6-0
2-6-0 2-10-2		4-6-2
2-6-2 2-10-4		
2-8-0		

Locomotives with main rods of the tandem type, when handled dead in train with all side rods, main rods and crossheads in place and connected, or with main and tandem crank pins equipped with authorized crank pin weights, are not to be moved faster than 35 miles per hour. All other locomotives, when handled dead in trains with main rods removed and all side rods in position, are not to be moved faster than 20 miles per hour.

If a tire is broken or an axle is broken, necessitating the swinging of one pair of driving wheels, the speed should not exceed ten miles per hour (one mile in six minutes).

Locomotives handled dead in train must be separated from locomotive pulling train by at least five freight car lengths. If two or more dead locomotives are handled in the same train, they must be separated from each other by at least five freight car lengths.

Locomotives handled dead in train must have air brakes on drivers and tender trucks, and on engine truck and trailer if equipped with brakes, cut in and operative unless defects are present, such as broken axles, broken tires, etc., which would make it unsafe to operate the brakes. When such defects exist, brakes on as many wheels as possible should be cut in and working.

Brake pipe cut-out cock under automatic brake valve should be closed and wired in closed position to prevent accidental movement to open position.

GENERAL INSTRUCTIONS FOR ENGINEERS AND FIREMEN

On reporting for duty at terminals, after complying with rules relative to registering, the engineer and fireman must examine work reports to determine what work has previously been reported on the locomotive which they are to take charge of. On arrival at the locomotive determine if the locomotive is properly equipped with the necessary supplies, in the way of lubricating oils, fuel and water, sand and proper tools; also signal equipment such as lights, fusees, flags and torpedoes. Know also that the proper firing tools are on the locomotive and that they are in good condition. Observe the condition of the various gauges for registering steam and air pressures, see that all lights are in good condition and operative. It is very important that the engineer and fireman should know positively that the water glass is registering correctly, and in order to insure this the water glass should be blown out each trip when taking charge of a locomotive, and the gauge cocks should be tried to know that they are in good working order. In blowing out the water glass see that the water glass guard is in place, close the top and bottom water glass cocks, open the drain cock and note if both water cocks are tight, in case it is necessary to apply a water glass at any time. Then open the bottom water glass cock and blow it out thoroughly, then close it. Then open the top water glass cock and thoroughly blow it out, then close the drain cock and open the bottom water glass cock, see that the water rises promptly in the glass. In case water does not register properly on closing the drain cock, have the water glass cocks examined to determine the trouble. **If the water glass cocks are not opened two full turns (two complete revoutions) the flow of water from the boiler to the water glass may be restricted, because the opening past the valve stem at its seat is not wide open** and does not provide an opening equal to the size of the openings from the boiler to the water glass. Do not simply grasp the wheel and turn it two turns while holding the wheel, but the wheel must be revolved a sufficient number of times to turn it two complete revolutions. The top and bottom water glass cocks must be opened two full turns (two complete revolutions) at all times while locomotive is under steam and the water glass properly in place. When steam is being used from the boiler, circulation is established, which causes the water to increase its agitation in the glass and when the locomotive is moving, the motion of the boiler is transferred to the water, which adds to the agitation caused by circulation due to the generation of steam. Thus, when a locomotive is standing and no steam is being used from the boiler, the water in the water glass will appear comparatively calm. However, when the throttle is opened, circulation is established throughout the boiler and the water tends to rise. If for any reason foaming of the water occurs, this causes the water throughout the boiler to raise higher than would be the case if no foaming took place, which shows a corresponding increase in the height of water as registered by the water glass. In order to lessen the disturbance of water as registered by the water glass and gauge cocks, due to agitation of water within the boiler, a water column is applied on certain locomotives where the application of such a device is considered desirable. Fig. 37 shows the above mentioned water column. Attached to this water column are three or four standard gauge cocks and one water glass. On the opposite side of the boiler head a standard water glass is applied directly to the boiler. The two water glasses forming a double check on the height of water over the crown sheet, and also broadening the view from different parts of the cab. When taking charge of a locomotive the gauge cocks should be opened to know that they are in good working order, and that they register the water level in the boiler as indicated by both water glasses. The water glass on the water column, and the water glass on the left side of the boiler head, should be thoroughly blown out, as described in the preceding paragraph. The water column should also be thoroughly blown out by opening the drain cock located below the column.

Before applying a new water glass tube make sure that all gaskets, pieces of broken glass, rubber, etc., are thoroughly cleaned out of the water glass cocks and the passages through the cocks are clean and free from obstructions.

Insert the new tube through the top cock passing it downward into the bottom cock.

When in position the lower end of the tube should be $\frac{1}{16}$" above lug or wire inside of bottom cock and should extend not less than ½" nor more than 2¼" into top cock. Tubes too short or too long to meet these requirements are not to be used.

Packing nuts around water glass tubes are to be tightened securely against gasket by hand. Do not use wrench unless leaks occur when nuts are tightened by hand.

Water glass guard must be properly applied around the glass before water glass cocks are opened. The guard must be kept in place around the glass at all times while the cocks are open and the boiler is under pressure.

The following procedure is to be followed when opening water glass cocks.

(a) Make sure that the guard is properly in place around the glass.

(b) Open drain valve wide open.

(c) Open top water glass cock slightly (about ½ turn) and allow a little steam to blow through the glass to warm it up.

(d) Open bottom water glass cock slightly (about ½ turn).

(e) Close drain valve slowly looking out for signs of failure in the glass and leaks around the gasket.

(f) If leaks occur open the drain valve and shut off both cocks before attempting to remove the guard or tighten the packing nuts.

Follow the procedure above outlined when opening water glass cocks after tightening nuts to stop leaks.

(g) When glass holds without leaking open both cocks two full turns (two complete revolutions).

(h) With both water glass cocks wide open and drain valve shut tight note the level of the water in the glass.

(i) Open and close drain valve several (two or three) times to make sure the water level is being correctly registered in the glass. The water should rise promptly to the same level each time the drain valve is closed.

Do not attempt to tighten a water glass packing nut without first closing both water glass cocks and opening drain valve wide open.

To determine whether there is a free circulation of water from boiler to the water column, the following test should be made.

Fill the boiler to two full gauges of water. Open the bottom gauge cock so the water will flow freely into the drip. Open the water glass drain valve. If water continues to flow from the bottom gauge cock it indicates the water is entering the column as fast as it is being discharged through the water glass drain. If dry steam appears at the gauge cock shortly after the water glass drain is open it is evident there is an obstruction to prevent the water from entering the column as fast as it is being discharged.

When the bottom water glass cock is open, if the top cock is not opened properly the water will be forced up into the glass and register a full glass of water even though the water is only at the height of the bottom water glass cock. After both water glass cocks are opened, the water should be blown out to make sure that it is registering correctly. Do not fail to have both water glass cocks properly open at all times, otherwise the water glass may indicate a full glass of water and it is vitally important that both the top and bottom cocks are open properly, to register the exact amount of water in boiler.

One of the first duties of the fireman on arrival at the locomotive is to examine the grate levers and see that they are in place and properly secured, and that grates are level, also see that ash pan has been properly cleaned and that dumps or slides are closed and properly secured. It is also his duty to inform the engineer upon arrival at the terminal, of any defects that may have developed during the trip which should be reported without fail. When necessary to clean the ash pan on the road do not neglect to wet down the ashes removed to reduce the hazard of fires, also level down the ashes so that pilots of other locomotives will not strike the pile and scatter fine ashes over the bearing surfaces underneath the locomotive. This is important, particularly at points where other trains do not stop or where locomotives pass such points at considerable speeds.

At the beginning of a trip the locomotive should be oiled around thoroughly, all parts such as chafing irons between locomotive and tender, boiler expansion plates, spring rigging where holes are provided or where found chafing, etc., should be oiled in addition to all moving parts of valve gear, driving box shoe and wedges, lateral plate of all wheels, in fact all moving parts of the locomotive which are in contact. In doing this an engineman should keep in mind that while a sufficient amount of lubrication of the different parts is necessary, excessive oil placed on any part is waste. For instance, a heavy coat of oil may be poured the full length of a guide and when the crosshead moves its first stroke, practically all of the oil will be pushed off the guide, whereas, had a small quantity been placed across the guide near crosshead, equal results in lubrication would have obtained without the waste. Oil holes to pins of the valve gear are often filled to overflowing, most of the oil running off to the ground. Two or three drops would have served the purpose as well.

In oiling around it should be noted that oil holes are open, packing in place where required, cellar keys or bolts in place and secured and that grease cellars have sufficient grease to make the trip. Bearings such as trailers and engine trucks, which receive top oiling should receive a fairly liberal quantity of oil at beginning of trip. Particular attention should be given to oiling of engine truck and driving wheel hubs and also trailer wheel hubs having inside journal boxes as lack of lubrication of these surfaces contribute to overheated bearings.

Lids of tender boxes should be kept closed as when they are left open, dust and dirt accumulates in the packing which dries it out and causes undue wear on bearings.

Grease cup plugs should be screwed down, until grease shows between bearings to insure that cups are filled and holes open.

Whenever there is an opportunity during the trip or shift, the locomotive should be inspected and bearings felt by hand to see that they are not beginning to overheat, and in this inspection oil should be applied to bearings which do excessive work, particularly trailers and engine trucks. Grease cup plugs

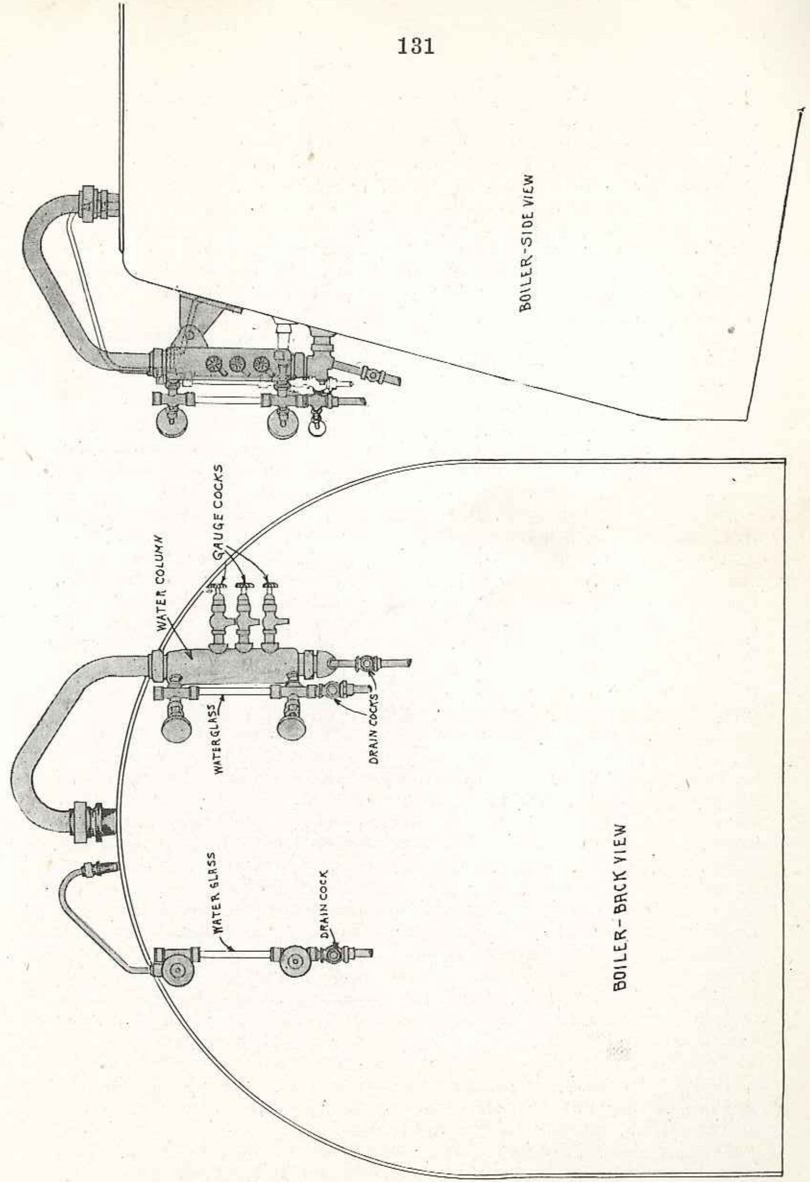


FIG. 37.
Arrangement of Water Column, Water Glasses and Gauge Cocks.

should be screwed down with sufficient frequency to insure proper lubrication of bearings.

When taking charge of a locomotive upon which any repairs have been made, inspect all visible parts to note the nature of repairs made, and whether completed. If any bearings have been worked upon, see that they receive proper lubrication; also if any new wheels have been applied, or truck brasses, see that the journal boxes or cellars are properly packed. If new packing rings are applied to cylinders or valves, or slide valves have been faced, see that they receive lubrication, particularly in beginning the trip.

It is the engineer's duty to supervise or direct the fireman in his work upon the locomotive, call his attention to improper practices which he notes and endeavor to give him all the information possible in line with his duties. The engineer must also familiarize himself with the locomotive and its appliances, in order that he might obtain the proper operation from them while on the road and be able to report intelligently any necessary repairs.

Note the water level in the boiler frequently, know at all times how much water you have in the boiler, opening the gauge cocks frequently to check against the water shown by the water glass, and on approaching the summit of grades, know positively that there is sufficient water in the boiler to permit of closing the throttle after passing the summit. If there is any doubt as to the height of water in the boiler, ease off on the throttle and try gauge cocks to make sure. Observe the steam gauge frequently to keep yourself advised of the steaming qualities of the locomotive.

When starting a train from state of rest insure that the locomotive will develop its full power by putting the reverse lever in full gear. Open the cylinder cocks, see that the rails are properly sanded, use no more throttle opening than necessary to gradually start the train. After the train has been started it should be observed that the entire train is intact, and that nothing has happened to cause the train to part. In handling light locomotives, in the absence of a conductor or pilot, the engineman and fireman should be governed by Operating Department Rules. In starting avoid jerking trains suddenly. In passenger service this is very annoying, as the heavy cars of today cause very disagreeable and damaging shocks. With freight trains such handling may cause damage to the lading or equipment and it is important that the start be made as gradually as possible.

The throttle valve is located near the top of the steam dome in order to remove it as far as possible from the water level in the boiler, so that the driest steam possible to obtain from the boiler will be passed to the cylinders.

Do not put so much water in the boiler when the locomotive is not working that priming or foaming will occur when the throttle is opened. This is particularly important when starting. When drifting on descending grades and approaching an

ascending grade, the conditions should be such at this time that the locomotive may be worked to full capacity and at a good speed approaching the ascending grade. When drifting the reverse lever should be moved toward full stroke sufficiently to prevent pounding of rods, using sufficient throttle opening to provide for drifting.

When drifting at high speed the reverse lever should be gradually dropped to half stroke but never below half stroke until the speed has materially reduced.

Inspect locomotive thoroughly at every opportunity. Remember that the maintenance of the locomotive as a whole depends largely upon the engineer and fireman in locating conditions which need attention. Do not depend upon anyone else for any condition in which you are concerned. Make it your business to know that any duties devolving on you are performed. Do not neglect to inspect the locomotive as far as possible at every stop over the division. Inspect bearings at every opportunity, to note their condition. In this way many conditions are found in advance and serious damage may be prevented.

At each stop where an inspection of the locomotive is made, or where bearings are oiled, note whether the sanders are working and whether sand is properly delivered to rails on both sides. If sand is used as directed, this inspection can be made. When oiling around see that oil holes are open so that bearings actually get lubrication.

Know that the water level in the water glass fluctuates in proportion to the moving of the locomotive. Where the water in the water glass seems to be almost at a stand-still when the locomotive is running, determine promptly whether the water glass is registering properly, by blowing out the water glass thoroughly, and trying the gauge cocks. Make sure that both water glass cocks are opened properly.

When foaming in a locomotive boiler occurs, great care is needed in the working of the locomotive, because water is being carried through the cylinders with the steam. Remember that under these conditions a boiler may be robbed of water very quickly, therefore reduce the use of steam until foaming has been overcome.

Do not leave a locomotive standing under steam unless the throttle is fastened shut, the reverse lever on the center, the cylinder cocks and relief valve open. If the locomotive is equipped with straight air brakes, such brake should be left applied. If a brake cannot be depended upon to hold the locomotive, and the grade conditions are such that the locomotive might move, see that the locomotive is properly blocked. When leaving a locomotive under these conditions leave the cylinder cocks open and the air pump running. When leaving locomotives at any time, know that there is sufficient water in the boiler and a proper fire to maintain locomotive until you return, also in freezing weather, see that injectors have heaters properly applied and that the train line and steam heat line valves are slightly open to provide for circulation at the rear of the tender. When leaving locomotives at terminals the same procedure should be carried out as leaving locomotives at any point, that is, sufficient water and fire should be left in the locomotive to protect the boiler until the locomotive can be taken care of by the roundhouse forces.

If there are any unusual conditions which might interfere with the proper handling of the locomotive by the roundhouse forces, such as the locomotive being broken down in any manner, or the air brakes not being operative, the roundhouse forces who handle the locomotive should be notified before they take charge.

Take advantage of every opportunity to make the locomotive perform its work at as short a cut-off and as wide a throttle opening as the conditions will permit; that is, if the locomotive does its work well with the reverse lever hooked up as far as possible and the throttle wide open, the work should be done in this manner. If necessary to vary from this manner of handling the locomotive, the above practice should be approached as closely as possible.

On ascending grades with heavy trains, when it is necessary to slow down for any reason, ease the throttle off a sufficient distance from the point of slow down to allow the grade to accomplish the necessary reduction in speed instead of working steam heavily very close to the point of slow down and then shutting the throttle and applying the brakes. This is particularly important when approaching or pulling out of side tracks, stations, etc., so that switches may be opened and closed without the necessity for making complete stops.

Should anything unusual occur that prevents proper firing of the locomotive it is better to reduce the amount of steam used and allow an opportunity to build up the fire than to continue the heavy use of steam until the steam pressure has been considerably reduced before easing off.

Do not fail to relieve cylinders and valve chambers of condensation at all times, because allowing locomotives to work water results in more broken cylinder and valve packing rings, cylinder heads, loose piston and damaged piston and valve rod packing, than all other causes combined.

Working water through the cylinders not only reduces the efficiency of the locomotive, but washes away lubrication on the surfaces of the valve seat and cylinder walls. This increases the difficulty of lubricating these surfaces, and adds to the rapid wear of such parts. When water is carried high enough to effect the conditions in the valve chambers and cylinders, all other devices about the locomotive which are operated by steam, such as the air pump, coal pushers, headlight generator, etc., will be more or less effected in the same manner as the valve chambers and cylinders.

To obtain the maximum power of the locomotive the reverse lever must be worked at the proper cut-off for various speeds

and loads, and the throttle opening must be regulated in accordance with same.

When the maximum load for the locomotive is being handled, or if the weight of the train is such as will permit, the throttle should be opened fully and the speed regulated by the position of the reverse lever. For economical operation, the reverse lever and throttle positions vary in proportion to the speed and load. For example, if, on approaching an ascending grade, the locomotive is operating at maximum speed under full throttle and the shortest possible cut-off, the speed should not be allowed to change greatly before increasing the cut-off by dropping the reverse lever down. It is the practice at times to allow the locomotive to slow down considerably before changing the reverse lever position and then drop the lever down five or six notches or even more. It is obvious that there is a point throughout the reduction in speed at which the reverse lever should have been moved down one or two notches at a time in order to maintain the maximum power and speed, and prevent the speed reducing in such a short distance. If the grade is uniform and the speed is allowed to reduce considerably before increasing the power of the locomotive it is impossible to again increase the speed, the time of negotiating the grade is increased and a longer cut-off must be used earlier with a possibility of the speed falling so low that the maximum power cannot be obtained at any position of the reverse lever. This often necessitating "doubling" on account of inability to handle the train over the grade. On the other hand, had the reverse lever been dropped down in proportion to the speed, a higher average speed would have been maintained, the maximum power of the locomotive would have been available and the final speed such that the train would have been handled over the grade successfully.

It is not expected that the exact reverse lever position for all operating conditions can be outlined, the judgment of the engineman is required to take into account the varying conditions of train load, power, speeds, etc. However, to the judgment of the engineman is intrusted the duty of obtaining the maximum service from the locomotive at the greatest possible economy, and for this reason any method that will produce the above results should appeal to the engineman's judgment.

The engineman should be as well versed in the performance of the locomotive at various speeds with different trains working under various throttle openings and reverse lever positions as in other matters effecting train operation. In order to obtain information in this respect the engineman should note the manner of operating the throttle and reverse lever under the various grade and train conditions, taking into account the fuel consumption in relation to speeds maintained to determine the most economical manner in which the locomotive will produce satisfactory service. The mere fact that a train is handled over a given distance in a certain time does not indicate that the best work has been obtained from the locomotive.

These suggestions apply equally to accelerating a train from its start. The engineman knows from experience that to obtain the maximum starting power, the reverse lever must be placed in full gear and as speed is attained the reverse lever must be hooked up as the speed increases, since allowing the reverse lever to remain in the corner prevents an increase in speed above a certain point, and as an increase in speed can only be obtained by increasing the power of the locomotive it is evident that there is a proper position of the reverse lever in proportion to the speed which produces the maximum power. The practice of allowing the reverse lever to remain in full gear in starting until a considerable speed is attained and then hooking the reverse lever up to a short cut-off at one time should be discouraged if it is desired to attain the maximum speed in the shortest possible time. The proper method is to hook the reverse lever up a notch or two at a time as the speed increases until the shortest cut-off at which the locomotive performs satisfactorily, has been reached, the throttle opening is to remain as near full open as the operating conditions will permit.

By giving these matters proper thought and acting on the suggestions offered, an improvement in the performance of the locomotive can readily be effected where there is room for such improvement.

Firemen should plan their work so that it will be possible for them to be in position to watch ahead on all curves to the left, and as nearly as possible, at all times when moving locomotives through yards.

TRAIN SPEEDS

As an aid in determining the rate of speed when moving slowly, the table below shows the miles per hour proportionate to the revolutions of the driving wheels. The revolutions of the driving wheels may be counted by watching the crosshead or by counting one for each four exhausts. By such observation the following table will enable the rate of speed to be determined for the various diameter driving wheels:

Diameter or Drivers..........	84″	79″	73″	69″	63″	57″	
Count Revolutions During.....	15	14	13	12	11	10	Seconds

Number of revolutions counted in number of seconds shown above, equals speed in miles per hour; for example, a locomotive having 63″ drivers, makes 15 revolutions in 11 seconds, according to the table, the rate of speed would be 15 miles per hour.

For the high speeds the time consumed between mile posts is most convenient and is shown as follows:

If a train covers the distance between two mile posts in the number of seconds given in the table below, the speed in miles per hour will be as shown:

Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour	Seconds per Mile	Miles per Hour
120	30.0	84	42.9	68	52.9
115	31.3	83	43.4	67	53.7
110	32.7	82	43.9	66	54.5
105	34.3	81	44.4	65	55.3
100	36.0	80	45.0	64	56.2
95	37.9	79	45.6	63	57.1
94	38.3	78	46.1	62	58.0
93	38.7	77	46.7	61	59.0
92	39.1	76	47.4	60	60.0
91	39.6	75	48.0	58	62.0
90	40.0	74	48.6	56	64.2
89	40.4	73	49.3	54	66.6
88	40.9	72	50.0	52	69.2
87	41.4	71	50.7	50	72.0
86	41.9	70	51.4	48	75.0
85	42.4	69	52.1	45	80.0

CONDENSATION AND FREEZING

When the temperature is low and there is a possibility of freezing, precaution must be taken to prevent parts which are not being used from freezing.

If the left injector or feed water pump is being used, "heater" should be put on right injector. To do this open drain or "frost cock" at front end of branch pipe, close steam valve at fountain, close overflow valve and leave water valve open, then pull the injector handle wide open. Now slightly open steam valve at fountain until there is a good flow of steam from the cock at front end of branch pipe and a light popping sound is heard, caused by steam, in the tank hose.

There should be a light flow of steam to headlight generator, blower line, steam heat line, coal pusher cylinder and all parts liable to freeze when they are not being used.

In case steam pressure cannot be maintained, or in other words if a locomotive is to be "killed" in freezing weather where it cannot be placed in a roundhouse, it must be thoroughly drained. In doing this make sure that cylinder cocks are open or remove them. If branch pipes are not provided with drain cocks at their lowest point, disconnect them. Drain air pumps, feed water pump, headlight generators, and feed water heater. Disconnect pipes leading to steam gauges and blow them out so that water will be gotten out of the coils in these pipes and out of tubes inside gauges. Disconnect tank hose and all pipes which may have water pocketed in them which will freeze.

SAFETY VALVES—STEAM GAUGE PRESSURE

Steam pressure as indicated on a steam gauge, is the pressure of the steam above atmospheric pressure, which is 14.7 pounds at sea level. To prevent the steam pressure from rising above that specified for the boiler, safety valves are provided. These are usually located on top of the steam dome, although in many cases they are located on an individual or auxiliary dome smaller than the main steam dome. The safety valves are for the purpose of relieving the pressure in the boiler in case it rises above the amount for which the safety valves are adjusted. With modern locomotives two or more safety valves are applied, so that in the event of one becoming inoperative, or if it does not properly relieve the pressure, the others will operate. The duty of the boiler is to generate steam only for the purpose of performing useful work, any escape of steam which does not perform some such work is a total loss. Therefore do not generate steam faster than it is used, and permit it to be blown away through the safety valves. Ordinarily if the safety valves pop or blow off for one minute, enough steam is blown away to necessitate burning one shovelful of coal or about fifteen pounds. This coal and the labor of handling it is a total loss.

The safety valve used upon locomotive boilers to regulate

the steam pressure therein is illustrated in Fig. 38. Where two safety valves are applied, one of them is adjusted to blow at the standard pressure for the boiler, the second safety valve is adjusted to blow at two pounds above this pressure. Where three safety valves are employed, the first one is adjusted to blow at the standard pressure for the boiler, the second one adjusted to blow at two pounds above this pressure, and the third one adjusted to blow five pounds above the standard pressure.

The safety valves are properly adjusted when applied to the locomotive, and their adjustment should not be disturbed. After the safety valves are properly adjusted they are locked with a seal, which must be broken which will provide for removing a cap to permit of turning the adjusting screw.

In case a safety valve spring was broken, so that the valve blowed continuously when the steam pressure reduced below that standard to the boiler, the adjusting screw 4 may be screwed down until the stem is forced down solid on valve 11, thus holding it tightly to its seat.

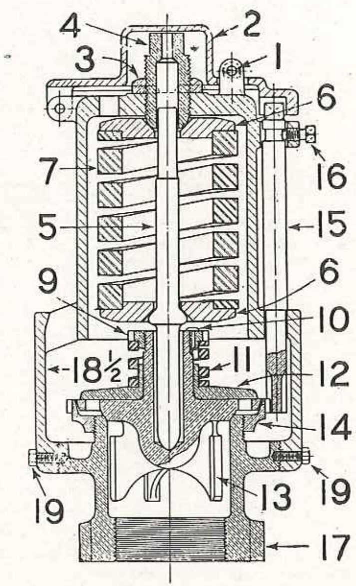


FIG. 38.

Safety Valve.

USE OF BLOWER

The blower is provided to create draft through the firebox when firing up locomotives or at other times when locomotives are not working steam, when necessary to increase steam pressure or admit water to boiler. In oil burning locomotives it should never be used more heavily than just the amount necessary to keep the stack clear of black smoke, and in coal burning locomotives the blower should be regulated in accordance with the condition of the fire, keeping in mind that the lighter fire in the box the lighter the blower should be used.

An excessive use of the blower can produce very bad effects on the flues and firebox sheets by causing cold air to be admitted, and its excessive use should be avoided.

The excessive or unnecessary use of the blower is forbidden. In cleaning fires or working about the firebox, the blower should only be used heavy enough to carry away the dust and gases. The blower should not be used heavily unless the firebox contains a fire similar to that which obtains when the locomotive is working steam, ie., a good hot fire all over the grate surface.

MOVING LOCOMOTIVES

Never move a locomotive unless it is known that the locomotive is in condition to move, that the proper pressures are available for operating the brakes, reverse gear, etc., and that there is no one working under or around the locomotive who may be injured by such moving.

GRATES AND FRONT END APPLIANCES

Move grates but slightly on any occasion when engine crew is in charge. When grates are shaken too hard, the cinders and dead ashes are thrown up into the fire where they fuse or melt and run to the grates and harden into clinkers or slag, causing hard working or stuck grates. Excessive use of the rake will produce a similar result. Therefore grates should be shaken lightly, just sufficient to break any crust that may be forming below the fire. Sometimes one is tempted to break up a banked fire by giving the grates a violent shaking. Do not do so, but use the rake lightly instead.

Should anything occur in the front end or smoke box to obstruct the free flow of air or gases from the flues to the smoke stack, the steaming qualities of the locomotive will be interfered with. The draft plates may be out of place, which would obstruct the proper flow of air and gases. The steam pipes or nozzle joints may be leaking, which would tend to blow the gases back toward the firebox. In the case of superheater locomotives, the unit joints may be leaking or the superheater tubes may be split or leaking, which would have the same effect as the steam pipe or nozzle joints leaking.

If grates are burned out or broken, repairs can sometimes be made by using angle bars or scrap iron to cover the broken

grates. Before proceeding it should be known that the ash pan is cleaned sufficiently to admit plenty of air.

POOR STEAMING QUALITIES

When a locomotive fails for steam the engineer should, at the first opportunity when it is safe for him, watch the performance of the fireman as to whether the locomotive is apparently being properly fired. See whether the conditions in the firebox are good or bad. If the method of firing is apparently good and the fire is maintained in as good condition as possible and it is necessary to stop on account of low steam, it should be determined if the locomotive is leaking in the firebox, or if there is any obstructions in the ash pan that would interfere with the proper admission of air to the fire.

In case of an oil burner see that there is no obstruction which will prevent the proper distribution of oil.

See that the fire is clean, so that the air can get through. Inspect the outside of the front end to find out whether or not something has gone wrong that would admit an excessive amount of air to the smokebox. It may be that the hand-hole plate is missing, or that for some other reason too much air is being admitted to the smokebox.

If conditions are very bad, necessitating excessive delay and the trouble has not been located, examine the interior of the front end to see that the draft plates or inside extension stack has not become loosened and out of place. This should be particularly looked out for if the locomotive is located on a branch line where forces to carry out such work are limited.

The fire should be kept as clean as possible, cleaning the fire if necessary to accomplish this, and proceed to the best advantage that the conditions will permit.

Do not stop to blow up for steam unless conditions make this necessary, favor the locomotive at every opportunity, such as drifting on descending grades, or by working the locomotive lighter. Avoid as far as possible using the injector when locomotive is not working steam. Make every effort to discover the cause which is effecting the steaming qualities of the locomotive, making proper report so that repairs might be made.

MAINTAINING WATER IN BOILER

Keep the water in sight in the water glass. If it goes below the bottom nut so it will not register in the glass, immediate steps should be taken to deaden the fire.

In closing the throttle, if it is found that the water in the boiler lowers so that there is no indication of water in the water glass, the throttle should be again opened to maintain the water in sight in the glass, if possible; and the water supply to the boiler increased until the throttle may be closed without causing the water to lower to a point where the water glass will not register the water level.

WORK REPORTS

Do not make blanket reports. In reporting leaks in firebox report definitely the location of all leaks observed on the trip. The conditions when the locomotive arrives in the roundhouse may not disclose them as readily as when locomotive was hot and working.

On arrival at terminals inspect the locomotive thoroughly, make a thorough inspection in the cab of all fittings and appliances, examining the firebox sheets and flues, arch and arch tubes. Inspect thoroughly the connections between the locomotive and tender. Also give all parts of the locomotive and tender a thorough inspection, reporting clearly and definitely all necessary work which should be performed. In making reports of any kind endeavor to make them in a clear manner so that there can be no mistake as to their meaning. Report all necessary work on locomotives under your charge on arrival at terminals.

USE OF SAND TO PREVENT DRIVING WHEELS SLIPPING

It is well known that the use of sand will cause the wheels to grip the rails and thereby reduce the liability of drivers slipping or wheels sliding. When the rails are slippery, such as is the case during rainy or frosty weather, the adhesion between the wheel and rail is very low, therefore even light brake applications may cause the wheels to slide, particularly at low speed and under these conditions enginemen should use care to see that the rail is sanded whenever there is liability of wheels slipping or sliding when starting or stopping trains or locomotives.

In starting from state of rest, sand should be used until sufficient speed is attained so that slipping will not occur. The slipping of drivers is very destructive to rails because the drivers will cut grooves into the rails which later may cause the rails to break as trains pass over them at high speed. It also wears the driving tires rapidly and causes a waste of fuel and water, in addition enormous strains are set up throughout the frames and driving axles and other parts of machinery which may later on lead to failure of these parts.

If the drivers do slip, never apply sand while the wheels are slipping, because to do so may cause the pair of wheels which receive sand first to stop slipping suddenly, the frames, rods, and crank pins are then required to stop the other pairs of wheels at the same instant which causes very damaging stresses. This contributes to broken crank pins, driving axles, frames, side rods, fractured cylinder castings, cylinder heads and other damage to machinery. Always close the throttle to stop slipping before applying sand to rails.

The sand pipes on both sides of a locomotive should be kept open because if the sand only runs on one rail the wheels on that side will grip the rail while those on the other side may tend to slip, setting up very heavy twisting stresses in the axles and heavy stresses in crank pins, rods and frames.

If sand is applied while a locomotive is slipping, with the sand operating on only one side, it increases the chances for failure of side rods, crank pins, axles and other parts of machinery.

In stopping, sand should be used at least thirty or forty feet before stop is completed and a greater distance than this if the rail is in bad condition and wheel sliding liable to occur. Enginemen should make a regular practice of stopping with the driving wheels on sand, as stated above, whether the rail conditions are good or bad. Any defects in sanders, piping or other conditions which prevent the proper operation of sanders should be promptly reported.

Special instructions prohibit the use of sand at certain locations, otherwise sand should be used in all stops, and starts, or to prevent slipping, while moving.

In ascending grades or curves, where locomotives are being worked heavily at low speeds, particularly with locomotives having long wheel base, there is more tendency for slipping than is the case with locomotives having a short wheel base. Under these conditions use sand frequently, even though slipping does not occur, particularly during weather when moisture accumulates on the rail, and there is liability of moisture accumulating in the sand pipes. Operating the sanders frequently maintains them in an operative condition.

The best practice is to use sand intermittently for short periods, say a few seconds at a time. The application being only sufficiently frequent to prevent slipping. On approaching road crossings, or other points where the rail conditions may be unusually conducive to slipping, apply sand before slipping occurs, the idea being to protect the locomotive against slipping in advance as far as it is possible to do so.

On heavy grades and curves it may be necessary to use sand almost continuously, if possible avoid using a heavy layer of sand. Large quantities of sand on the rail add to the resistance of the train. If necessary to avoid slipping use the maximum amount of sand obtainable.

When handling a long heavy train do not let the speed reduce to a point where bad slack action is set up throughout the train on account of slipping, due to sanders not working. Such a condition is brought about by the speed falling to a point where one end of the train stops or nearly stops when slipping occurs. If the slack is jerked out of the train heavily each time after slipping occurs, it is advisable to stop and get the sand pipes open. Continued slipping under these conditions very often causes the train to part.

The tractive power, or cylinder power of the modern locomotive is very close to the wheel adhesion on the rail, that is, a great margin in weight on the wheels is not allowed over the power of the cylinder to turn the wheels, therefore, if the rail is not dry the adhesion is very much reduced and slipping of the driving wheels occurs very easily, therefore, do not attempt to start a locomotive suddenly under any condition. Do not forget that when a locomotive is operating on curves, that the wheel adhesion on all driving wheels is not uniform, and that slipping is more apt to occur when working a locomotive at low speeds and under heavy work; the power in the cylinders will, many times, apparently switch the entire locomotive from side to side. Under such conditions look out for slipping. Slipping the driving wheels is throwing away power that should be used to propel the locomotive, and tires and rails are badly damaged. Repetition of this necessitates their renewal. When slipping occurs one pair of wheels is liable to stop slipping or attempt to stop considerably in advance of another pair. This throws very heavy stresses on crank pins, rods, frames and their connections, therefore do not use sand while a locomotive is slipping, even with the throttle closed; wait until the locomotive stops slipping, then start the sand. When the sand pipes operate only on one side, make it a point to get the other sand pipe operating, or else avoid the use of sand entirely, if possible. Slipping of locomotives is the most prolific cause of progressive fractures which finally result in serious break-downs. Violent slipping of the driving wheels may result in the failure of side rods or other parts which may lead to the personal injury of the engineer or fireman.

When rail conditions are so bad that continued slipping of the drivers takes place, even though sand is used, do not attempt to work a heavy throttle with the reverse lever hooked up toward the center. Work the reverse lever near full stroke with only sufficient throttle to keep the train moving, until conditions are such that the speed may be increased and the reverse lever hooked up and the throttle opened wide. The above method should be resorted to only in cases where the rail conditions are very bad, or where continued slipping occurs, such as might be the case in handling heavy trains in starting or on ascending grades, etc. Working a light throttle under these conditions reduces the tendency for the drivers to slip, and if the wheels do start to slip the steam pressure in the cylinders reduces rapidly so that violent slipping does not take place.

MECHANICAL STOKER

The mechanical stoker is designed to relieve the fireman of the labor of firing by hand, the stoker firing the locomotive mechanically, with small coal scattered over all parts of the grate area continually. This continuous delivery of coal in small particles over the entire grate area is under the fireman's control. Since there is no manual labor connected with the operation of such stokers the maximum capacity of even the heaviest locomotives might be obtained without taxing the strength of the fireman.

The operation of the mechanical stoker and the travel of the coal is illustrated by numbers in Fig. 39, and is as follows:

The shovel sheet is provided with an opening 18 inches wide, extending from the coal gates to the slope sheet of the tank. The opening is covered by slides each measuring about 20 inches in length. After passing through this opening to the trough (1) beneath, the coal is conveyed by the helicoid Conveyor Screw (2)

through the crushing zone (4)—where the coal forced against the crusher plate by the screw is broken to a suitable size—to the Transfer Hopper (9), where it is divided, eually or unequally, according to the positions of the dividing rib (18), between the two Elevators (10) and (19). In these Elevator Casings are Elevator Screws (11), which elevate the coal and drop it into tubes fitted into Elbows (16) and (17), which tubes extend through holes in the back-head on each side of the fire door. Constant steam jets in the elbows blow the coal through the tubes above mentioned, which are fitted with Distributors (11) and (12), located on the inside of the firebox. These distributors deflect and spread the coal over the entire surface of the fire.

The elevating screws are driven by gears which mesh with a rack reciprocated by the Driving Engine (5), and the conveyor screw is driven by a Driving Shaft (26), also meshed into this rack, secured along the side of the trough and geared at (32).

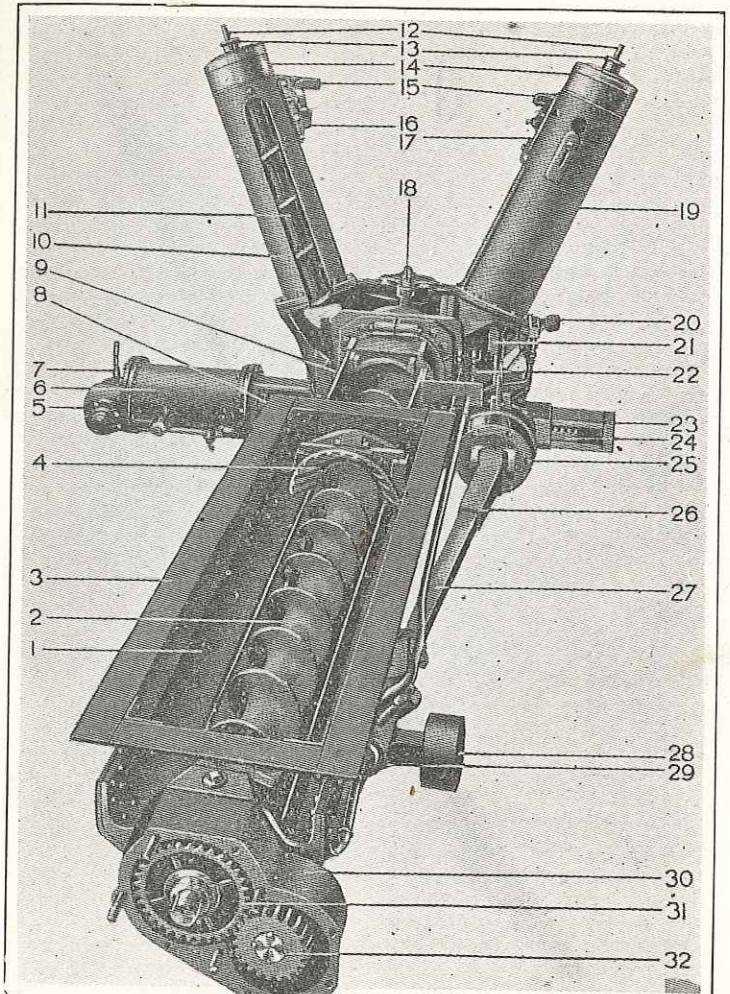


FIG. 39.

Duplex Stoker.

DRIVING ENGINE

Fig. 40 shows the driving engine which consists of a cylinder of eleven-inch bore and a stroke of seventeen and three- quarter inches, with piston and reverse head. It is operated by steam taken from the locomotive turret reduced in pressure by throttling through a one-half inch globe valve.

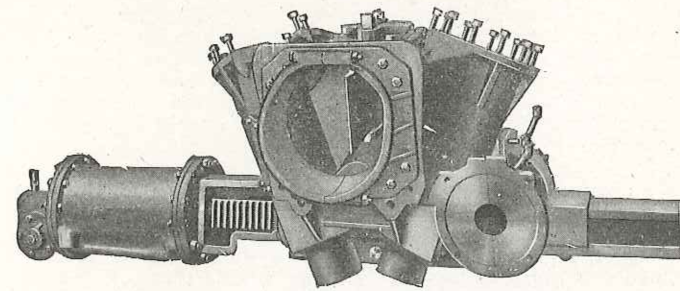


FIG. 40.

Stoker Engine and Transfer Hopper.

The pressure of the steam used by this engine varies from eight to eighty pounds, according to the work required by the quality and size of the coal, and its pressure is indicated by a special driving engine steam gauge located on the boiler head, connected in this line between globe valve and cylinder. In normal operation, the piston has a power stroke in one direction only. This is when the piston is traveling in toward the center line of the locomotive and the entire stoker mechanism is in normal operation, since on the return stroke of the piston the conveying mechanism is stationary; but when any one or all of the three screws—two elevator and one conveyor—are reversed by means of their individual reverse mechanisms, the return stroke of the piston becomes temporarily a power stroke. By this it can be seen that only a very small percentage of the full boiler pressure is required for the return stroke except when the reversing of any of the screws is necessary.

The operation of this cylinder is controlled by a reverse head, to which is connected by proper ports and passages, almost identical with the reverse head used on the Westinghouse eleven inch air pump, although not interchangeable. The piston rod screws into the rack or stoker main driver, hereinafter described. The reverse head is bolted to the outer end of the driving engine cylinder, and the admission ports to the cylinder are so arranged that if the piston makes a sudden movement, such as might be the case if a clog occurred in the conveyor or elevators, and then broke loose, a small percentage of the steam is trapped in either end of the cylinder which forms a cushion to prevent breaking the piston or knocking off the reversing head.

The reverse head is operated by means of a small reverse rod which operates in the hollow piston rod, in a manner identical with the reversing rod used on Westinghouse air pumps.

In case the stoker becomes clogged on any foreign material, or it is desired to reverse it for any reason, the operating rod located on the back head of the locomotive boiler, if the piston is making a power stroke, is moved to its lower position, and if the piston is making a return stroke, to its upper position. This moves a small valve in the auxiliary head bolted to the reverse head, so that the reverse head valve throws steam into the opposite end of the cylinder and causes the piston to change its direction. The return of the operating rod handle to a central position causes the driving engine to resume its normal operation.

It is always necessary to reverse the driving engine whenever a clog occurs and it is desired to reverse either of the elevator screws or the conveyor screw. The reason for this is that in case of a clog the pawls in the elevator or conveyor screw reverses are held so tightly against the ratchet wheels that it is impossible to lift them from the teeth unless the pressure is relieved by reversing the driving engine.

Unlike the ordinary high speed engine, there is in this driving engine an enormous reserve power, which is absolutely necessary for the work to be performed, i. e., the crushing of coal with its varying physical properties. With the low steam pressure needed by this engine for normal operation, and the great differences between it and main steam line pressure, it can be seen that when the task to be performed increases it is merely a question of the steam pressure building up in the cylinder to the point required for that task.

DISTRIBUTION OR SPREADING SYSTEM

The starting of the coal towards the two firing zones or areas in the firebox is done by the elevators, as explained, but the actual spreading of the coal over the two overlapping zones, or areas, is accomplished through the means of the two firing points at the two stoker openings through the back-head of the locomotive boiler. The fire door is left undisturbed so that it can be used for hand firing at roundhouse and on sidings, or when drifting.

Two elbows, Fig. 41, in the back bottom portion of which firing nozzles are secured by means of set screws, are bolted to the elevator casings. Distributors and tubes combined are attached to these elbows, the tube extending through the openings in the back-head and the distributor being on the inside of the firebox.

The distributor tubes serve as a firing plate and the coal is blown through the tubes on the under side of the distributors by the jets of steam admitted to the firing nozzle, an intermittent action being secured through the constant steam jet and the

stopping of coal elevation during the return stroke of the driving engine piston and rack.

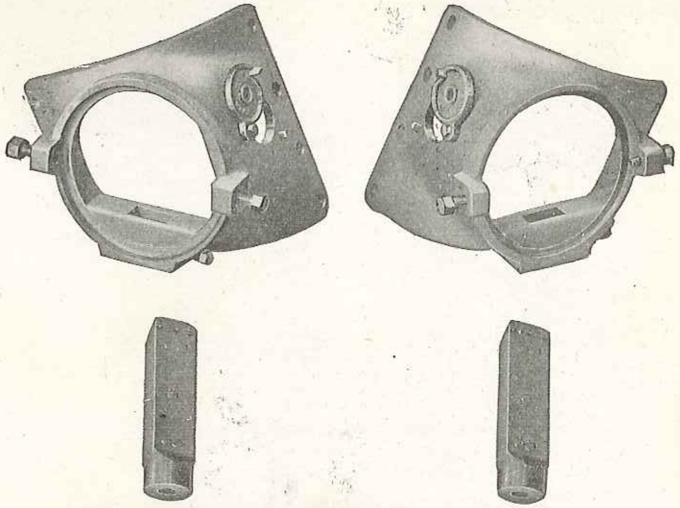


FIG. 41.

Stoker Elevator Elbows and Firing Nozzles.

The elbows are provided with peep holes with swinging covers through which the coal supply can be observed, and the condition of the fire can be seen through peep holes in the tops of the elevator casings.

The deflecting ribs on the distributors are so arranged as to distribute the coal in such a manner that all parts of the grate area will be served to the best advantage, the two firing zones, or areas, overlapping along the center where the combustion area is greatest.

The distributor tubes are made of cast steel and are of the design shown in Fig. 42. They are secured to the elbows by means of bolts and it is but a moment's work to replace them when necessary.

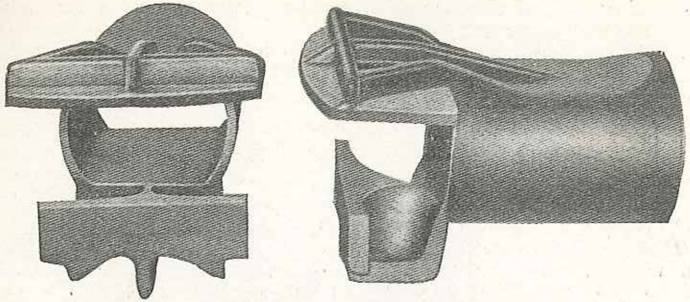


FIG. 42.

Stoker Distributor Tubes.

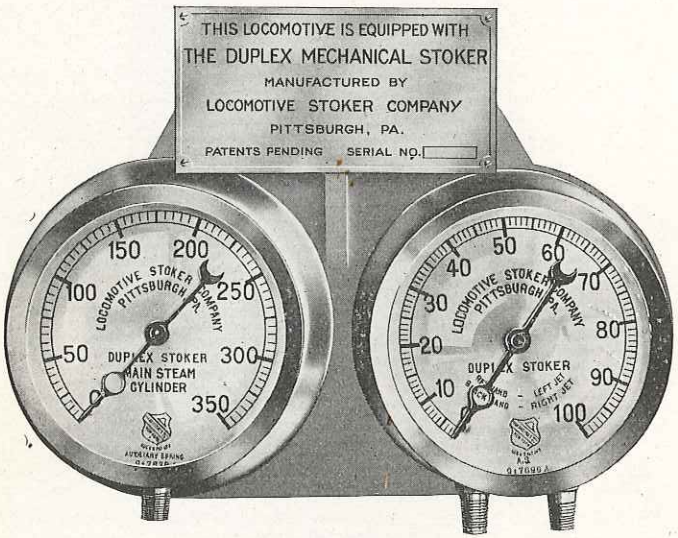


FIG. 43.

Stoker Operating Gauges.

GAUGES

Fig. 43 shows the two steam gauges which are set in a bracket, secured to the back-head of the locomotive boiler in a position where they can be easily read by the fireman.

The driving engine gauge on the left indicates the pressure of steam used by the driving engine. The one on the right has two indicators, the red indicator showing the steam pressure on the jet in the left elbow, and the black indicator, the pressure on the jet in the right elbow.

OILING

All stokers should be oiled before leaving terminal, and on long divisions oil holes should be filled between terminals. The points of oiling are as follows:

The driving engine is oiled by tapping into the driving engine steam inlet line an individual small lubricator. The valve to which should be turned on before starting stoker.

Before the locomotive is put in service either new or after an overhauling in the shop, the rack in the rack housing should receive an initial mixture of one quart of black engine oil. There is a one-inch elbow tapped into the separator cover on the left back side of the rack housing provided for this purpose.

Left and right elevator drivers and reverses are lubricated by lifting the pawl shifters on top of the elevators. When first putting stoker into service about one quart of oil should be poured into each reverse in this manner.

Small holes are located in elevator drive and reverse casings each of which leads to a cored passage in casing provided to lubricate bearing on which elevator drive and reverse rotates.

The left elevator driving shaft bearing in bottom of transfer hopper is lubricated by a special tap on the left side of transfer hopper under locomotive deck.

The right elevator driving shaft bearing and the conveyor drive and reverse receive their lubrication through an oil box, usually stuffed with curled hair, with four outlets. This box should be filled every trip. This oil box should be cleaned out occasionally, particularly when considerable dust and dirt has accumulated.

The conveyor driving shaft bearings in the slide support and gear casing are oiled by cups secured to the trough under the apron between locomotive and tender. These should be filled once each trip.

The grease boxes in the gear casing and gear casing cover on the rear of the conveyor should be filled at least once a month with soft grease and once in three months the gear casing cover should be removed and the gears packed in grease.

Universal joints, slip joints and conveyor slide support rollers should be oiled once each trip with engine oil.

Use valve oil in the lubricator for the driving engine. Use engine oil for other parts, except the conveyor gear casing. See that the lubricator is feeding when the stoker driving engine is running. When the stoker engine is shut off, such as in standing or drifting, shut the lubricator off.

TO START AND OPERATE STOKER

Referring to Fig. 44. First open main valve No. 1 at the fountain, then open valve No. 2, next open valve No. 3, which allows the steam to flow to the distributor jet line. Valves Nos. 4 and 5 should then be opened sufficiently to register about 15 pounds upon the jet steam gauge. Always see that steam is blowing through the jets before starting the stoker engine.

To start the stoker engine place the operating lever No. 10 in its central or running position. Place conveyor reversing lever No. 12 in forward position. See that valve No. 8 to the exhaust line is open. Valve No. 9 should be kept closed except when it is desired to moisten the coal with exhaust steam. See that the lubricator to the stoker engine is feeding properly. Valve No. 6 should be opened slightly and allowed to remain in that position until the stoker engine has made several strokes slowly, if the stoker engine has been standing some time, in order to work the condensation out of the stoker engine cylinder. Valve No. 7 should be kept closed except when necessary to obtain more power to crush a particular hard lump of coal. When this valve is open steam pressure increases very rapidly in the stoker engine cylinder. As soon as the heavy duty crushing is performed valve No. 7 should be closed, and the stoker operated with steam through valve No. 6.

Open the first slide plate No. 29, in the floor of the coal pit of the tender by pulling it ahead with a hook. This allows coal to feed into the stoker conveyor. The slide plate should not be opened full length, but just far enough to feed coal at the proper rate to the conveyor. When lump coal is used the slide plate must, of course, be opened wider than with slack coal.

The stoker should be run slowly at first, feeding just sufficient coal to supply the fire for the work being done by the locomotive. On extra light runs the stoker will have to be shut off frequently for short intervals. Do not feed too much coal, carry a light fire. In firing with the stoker the fire should be lighter than is the case in hand firing.

To reverse the conveyor screw in the tank lower handle No. 10 to bottom position. Move screw conveyor reverse lever No. 12 to rear or reverse position. Raise handle No. 10 to center position. This reverses the screw in the tank.

To stop conveyor screw in tank place conveyor reverse lever No. 12 in center position. If reverse lever No. 12 does not move freely lower handle No. 10 to bottom position and then to center before attempting to move the reverse lever.

CAUTION

Return stoker piston to dead position against cylinder head by lowering handle No. 10 and shut off steam to stoker engine by closing valves in steam line before trying to remove obstructions in stoker or doing any work on stoker.

Keep hands out of stoker elevators and conveyors unless steam is shut off to stoker engine and handle No. 10 moved to its lowest position.

Do not put a bar, rod or lever in stoker unless the above precaution is observed.

Do not step in the stoker conveyor.

To reverse the right or left elevator screw raise the pawl shifter No. 26 on top of vertical shaft to upper position. Stop the conveyor screw before reversing the elevator screws or the stoker will be jammed with coal.

To stop the right or left elevator screw raise elevator pawl shifter No. 26 on top of elevator to middle position. Stop the conveyor before stopping the elevators or the stoker will be jammed with coal.

TO LOCATE CLOGS

In case the stoker stalls due to iron, slate or other foreign matter getting into the stoker machinery, first shut off steam pressure to the stoker engine cylinder by closing valves Nos. 6 and 7, move operating lever No. 10 to its lowest position, place the tender conveyor reverse lever No. 12 in center position, then place the right elevator pawl shifter No. 26 in its neutral or middle position. Now raise the operating valve lever No. 10 to its central position and open the steam valve No. 6 sufficiently to turn the left elevator to determine whether the obstruction is in the left elevator. If the left elevator operates properly cut in the right elevator by lowering pawl shifter No. 26, without increasing the steam pressure. If the stoker stops, evidently the obstruction is in the right elevator. If the stoker continues to operate properly the obstruction is in the tank conveyor.

With the D-2 stoker the conveyor screw and left elevator operate on the forward stroke of the driving engine, and the right elevator operates on the return stroke.

TO REMOVE CLOGS

DO NOT FORGET TO SHUT OFF THE STEAM TO THE STOKER ENGINE CYLINDER, BY CLOSING VALVES NOS. 6 AND 7, BEFORE ATTEMPTING TO REMOVE OBSTRUCTIONS OR WORK UPON THE STOKER.

The clogs in the upright elevators usually occur at the bottom of the elevator casing doors, catching between the flight of the conveyor and the bottom of the door.

To remove these clogs, raise the door in the engine deck and the obstruction can usually be seen and removed. However, if it is in the elevator, reverse the elevator screw forcing the obstruction back down into the transfer hopper. In case the obstruction is not located at this point it may be a small mine spike or other piece of metal which has gotten above this point. In that case remove the nut at the top of the elevator casing door, remove the door and the obstruction may be located and removed.

A clog in the tank conveyor will usually be found in the crusher zone. To remove a clog at this point reverse the tank conveyor screw in the manner described, forcing the obstruction out of the crusher when it can be removed from the trough.

Do not run the conveyor screw backward more than three revolutions.

COAL DISTRIBUTION IN FIREBOX

The distribution of coal is regulated by two separate attachments as follows:

Steam jets in elevator elbows.

Dividing rib in transfer hopper.

The steam jets fitted into the elevator elbows blow the coal over the grate area and are regulated according to the quality of coal. For coarse coal it requires about 18 pounds of steam, and for slack about 9 pounds of steam, on these jets to get an even distribution. The coarser the coal the more steam, and the finer the slack the less steam will be required. If, after running for some distance, it is found that too much coal is going to the flues, the steam pressure on the elbow jets should be reduced, and if not enough is going to the flues, it should be increased.

The dividing rib in starting out should be in the center of the transfer hopper. If it is found that too much coal is feeding to the right side of the firebox, the dividing rib should be turned to the right, and if too much is feeding to the left, the dividing rib should be turned to the left.

The amount of coal distributed over the firebox is regulated by the speed of the driving engine and the plates over the trough in the tender. To vary the amount of coal, the steam pressure should be increased or decreased by regulating the controller valve 6, Fig. 44. When it is seen that not enough coal is feeding into the trough another slide over the trough should be pulled back.

Before leaving terminal, see that fire is clean and in good condition. Build up a good level fire with shovel. After starting stoker as hereinbefore explained, open one or more slides in tank and be sure coal is getting to conveyor screw.

Do not feed iron, rock, slate or waste through the conveyor.

When train is standing on siding for a short period, shut stoker off by throwing operating rod on back-head of locomotive boiler out of running position. When train is to stand for a longer time, the driving engine should be cut out entirely by closing main steam line inlet and main lubricator connection and in winter time drain cocks should be opened.

If sufficient coal cannot be supplied front grates see if the distributors are warped out of shape and point too low. If such is the case, report should be made at terminal so that proper adjustment may be made. See that the steam jets are blowing freely, and are not plugged with pipe scale. It may be necessary to increase the pressure on these jets.

METHOD OF OPERATION

In firing with the stoker the practice is to build up a light even fire by hand and get up full steam pressure before leaving a terminal, and not bring the stoker into use until the locomotive is working steam. The fireman then opens distributor jets and starts driving engine, then opens first coal slide plate over conveyor trough, which starts the delivery of the coal to the firebox.

The screw conveyor is designed to furnish the amount of coal required under average conditions with stoker engine running at or below medium speed.

When the first of the slide plates is pulled forward, the coal, falling into the conveyor beneath, is carried by the heavy cast steel conveyor screw through the crushing zone at the forward end of the trough. Through this zone the slack and coal of a size suitable for efficient firing passes in a loose and free state without being crushed, while the large coal is broken and reduced to the best size for efficient firing. After passing through this zone the coal is delivered to the transfer hopper beneath the cab deck, where it is divided, equally or unequally, according to the position of the dividing rib, between the right and left elevators, and dropped into distributor elbows. Into these elbows are fitted distributor tubes which extend through the openings in the back-head on each side of the fire door, the distributor portion of each tube being located on the inside of the firebox over the grate area.

The distribution of coal over the grate area is accomplished by means of a low pressure constant steam jet located in the back and bottom portion of each distributor elbow. The pressure of the steam supplying the right and left jets is reduced from boiler pressure by throttling it through half inch globe valves, and this reduced pressure is indicated by a steam gauge connected to each jet line between globe valve in that line and elbow jet nozzle. The pressure of steam at these jets under working conditions varies from ten to twenty-five pounds. Interposed between the jet valves and the main steam line is a three-quarter inch globe valve, by which the steam may be cut off from the jet main line without disturbing the setting of the jet valves.

The distribution of coal over the grate area is regulated by varying the pressure of the elbow jets, as indicated by its individual pointer on steam gauge fastened to the back-head in full view of the fireman. The distributors have deflecting ribs especially designed for their function of spreading the coal, and this variation of jet pressure affects sufficient flexibility in firing different areas of the grate. The distribution overlaps the two areas or zones fired from the two elbows, which overlapping insures ample coal being supplied to center of firebox in heavier combustion area. By increasing the jet pressure on the right or left side more coal will be carried to the flues on that side, or by decreasing the jet pressure less coal will be carried to the flues and more to the middle and back portion of the grate area on that particular side.

The deflecting ribs on the distributors, as shown in Fig. 42, place some of the slack coal in right and left corners of firebox, thus preventing loss through stack. The fireman can direct more or less coal to each side of the firebox by changing position of the dividing rib, as shown in back view of transfer hopper, Fig. 40, by moving lever to either side.

By means of the elevator reverses and conveyor reverse, which as hereinafter described are an arrangement of ratchets and pawls, the two elevator screws and conveyor screw turn in one direction only, and coal is therefore conveyed and elevated only on the forward stroke of the engine. In this manner constant steam and intermittent supply of coal is secured.

The sliding plates at the bottom of the tank are located so that there will be a supply of coal at all times on top of the screw.

As coal is used from tender so that it no longer flows freely through first slide opening, the fireman opens next slide and so on until supply is again taken at coal chute, when slides are all pushed back and first slide opening used as in starting out.

With the distribution as described, a level white fire can be carried and perfect combustion secured. This level thin fire usually results in the firebox temperature being higher than with hand firing. Maintain a white, level fire, and if the locomotive has been steaming well for some distance and steam begins to reduce, do not materially increase the amount of coal being fed to the firebox, unless there has been a change in the working of the locomotive or an increase in the amount of water being supplied to the boiler. Observe if the fire needs attention. Forcing the stoker under such conditions causes clinkers to form which shuts off the supply of air through the grates, causes the fire to bank and become heavy and contributes to heavy losses of fuel.

Before taking coal close the tank opening with the slide cover plates. This should be done before any coal is put in the tender.

When it is desired to separate the locomotive and tender, the conveyor unit of the stoker should be left with the tender. This can be done by loosening the bolts on the left ball joint clamp and sliding the clamp to the left enough to free the conveyor ball joint and disconnecting pin connecting the block and universal joint jaw on the conveyor drive and reverse cover.

Do not leave the tank openings uncovered when coaling the tender.

Do not let coal stand in the conveyor trough between trips.

Do not allow coal to accumulate in the tank cut-out and become packed around the outside of the conveyor trough. This will break the trough when the locomotive is rounding a curve.

Never place a hand or foot in the trough while stoker is in motion.

Do not run the stoker without distributors. The distributors are designed to spread and save coal. Leaving them off means unnecessary waste of coal.

Leave a pressure of at least four pounds on stoker jets at all times when locomotive is fired up to prevent distributors being over-heated and damaged.

When approaching a terminal yard where locomotive is to be taken to roundhouse the slides should be closed and the conveyor and elevators should be emptied of coal. This operation should be started in sufficient time so that coal will be consumed in getting train into yard without creating black smoke. If, then, additional coal is required, it should be handled with the scoop.

The conveyor, hopper and elevators hold between 500 and 600 pounds of coal, and if this amount is placed in firebox after locomotive is detached from train or after arriving at roundhouse, most of it is wasted.

Before leaving a stoker locomotive at fire track, fireman should close driving engine throttle valve and steam jet main line valve tight, open drain cock on bottom of engine cylinder to eliminate any possibility of stoker engine freezing in extremely cold weather, and shut off the stoker lubricator.

DESCRIPTION OF THE STANDARD TYPE B AND MB STOKERS

As the Standard B and MB Stokers are generally same in principle and design, the operating instructions outlined in this book apply to both stokers. However, there is a difference in the construction of the two stokers, principally in the conveying systems, as illustrated in Fig. 46. The clevises and paddles connecting the screws, and the two hanging bearings supporting the front and tender screws used with the B Stoker are eliminated in the MB. Thus the conveying system of the MB is comprised of a continuous screw divided into three sections connected by universal joints.

The main units of the stokers are:

A tender trough located beneath the coal supply and rigidly secured to the tender frame.

A two-piece, telescopic intermediate unit with a ball joint at each end to provide the necessary element of flexibility between locomotive and tender.

A front unit consisting of a horizontal trough casting and an elbow-shaped conduit fastened to the locomotive frame, together with a vertical housing, protecting grates and firing table.

A distributor jet fastened to the back wall of the vertical housing just inside the firedoor and controlled through a manifold and valves located on the boiler backhead.

A separate, double-acting, two-cylinder, variable-speed, reversible steam engine which may be located either on the locomotive or tender.

On both the type B and type MB stokers the coal is conveyed through conduits beneath the locomotive deck and mudring, and thence upward through an elbow in vertical conduit

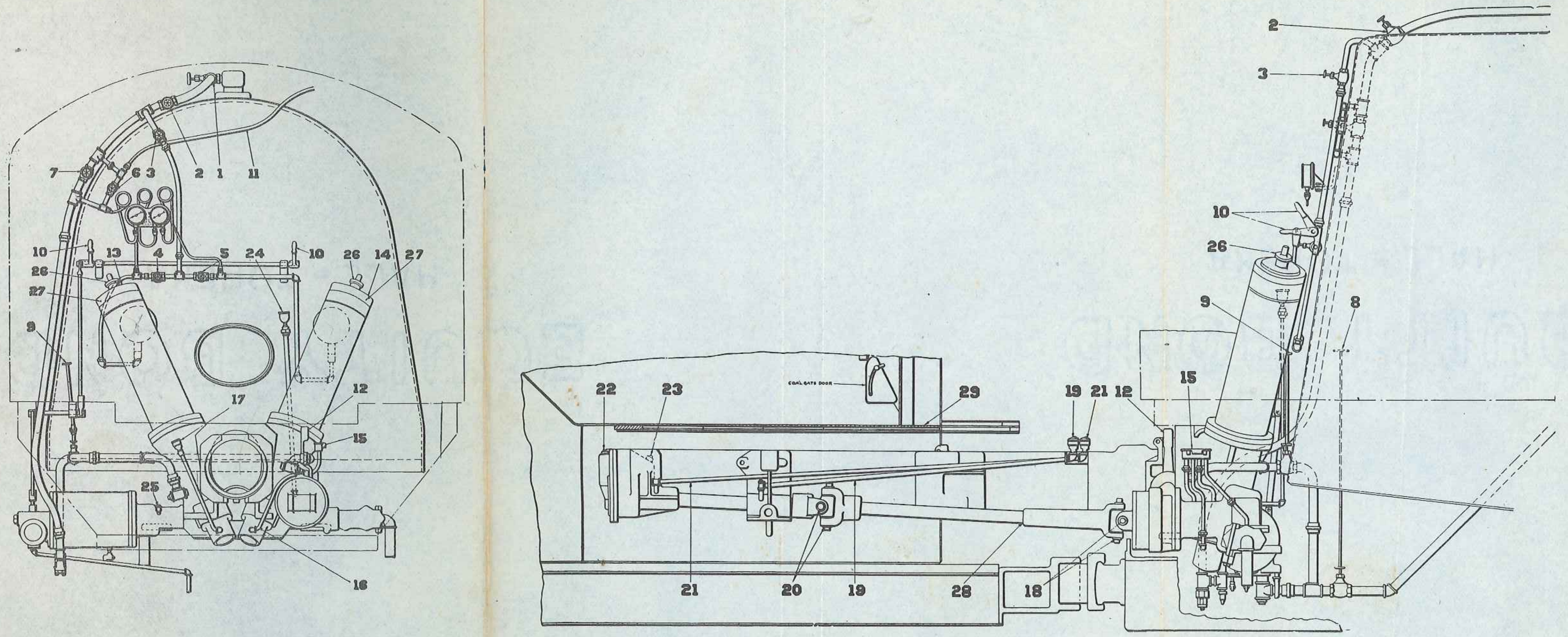


FIG. 44.
Duplex Stoker Arrangement.

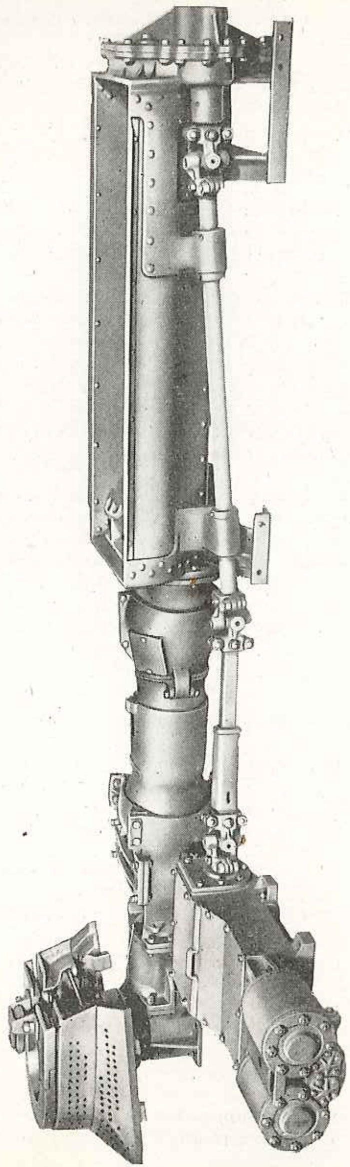


Fig. 45 Type MB Stoker.

which extends through the rear portion of the grates and terminating just below the firedoor opening. From this point the coal is distributed by steam jets. The only parts of the stoker in the locomotive cab are the jet manifold and valves and steam gauge, all located on the boiler backhead.

OPERATING INSTRUCTIONS

When a locomotive is placed on outgoing track to be turned over to the engine crew, the fire should be in good condition, free from banks, clinkers and excessive ash accumulation on the grates. The preparation of the fire before starting the stoker, which should not be used before locomotive is coupled to the train, should be done by hand and the fire should be heavy enough to withstand the high draft created when starting the train.

Before leaving terminal the fireman should check the oil level in the stoker engine bed. If oil appears when pet cock No. 7 is opened, there is a sufficient amount to insure proper lubrication of all parts within the engine bed. When additional oil is necessary, supply through filler pipe No. 8, using a good grade of engine oil.

A compartment oil box, No. 9, and in many instances a grease gun connection, No. 52, located at the front of the tender, supplies the lubricant necessary for the various conveyor trough bearings. The oil box also provides lubrication for the universal joints when the stoker engine is located on the tender. Fill each compartment with car or engine oil (do not use valve oil) at the beginning of the trip. When stoker engine is located on the locomotive the universal and slip joints between engine and tender should be oiled with other locomotive parts.

Adjust lubricator for stoker engine cylinders to feed three drops per minute.

To start the stoker, first open turret valves admitting steam to engine and jet lines, Nos. 1 and 2, respectively; next open main jet valve, No. 3; then open each of the manifold jet valves separately to see that jet holes are free from obstruction.

Place operating lever, No. 4, for stoker engine reverse valve in forward position. There are two designs of reverse valves as will be noted in Fig. 48, the principal difference being in the location of the internal valve when in forward or reverse position. The neutral or central position remains the same for both valves.

Open stoker engine valve, No. 5, slowly to permit cylinders to heat up and condensation to exhaust through automatic drain valve, No. 12. This valve will close when condensate has been released. The stoker engine valve can now be regulated for the desired speed.

Booster valve, No. 6, should be kept closed except in cases where it is necessary to increase the steam pressure to stoker engine rapidly in order to crush an exceptionally hard lump of coal. As soon as possible, valve No. 6 should be closed and stoker operated with steam through valve No. 5.

Pull the first slide plate forward to admit coal to the conveyor. Open firedoor for observation and as the coal reaches the top vertical housing, No. 17, adjust the five manifold jet valves to get an even distribution of coal over the entire grate area. On locomotives having exceptionally large fireboxes there are two additional jet valves, or a total of seven.

The valves for the "Left Front" and "Right Front" jet lines, Fig. 47, control the distribution of coal to the left and right front corners and adjacent sides of the firebox, through the holes in the left right top center portions of the distributor jet.

The valves for the "Left Back" and "Right Back" jet lines control the distribution of coal to the left and right back corners and adjacent sides of the firebox, through the holes in the extreme left and right sides of the distributor jet.

The valve for the center jet line controls the distribution of coal over the front and center of the firebox, through the holes in the center of the distributor jet.

For the average grade of coal 30 to 45 pounds manifold jet pressure should be sufficient to obtain proper distribution. However, these pressures are only approximate and a difference in coal size may necessitate a change. Any fluctuation in boiler pressure should be compensated for by adjusting main jet valve.

The speed of the stoker can be determined by observation of the front conveyor screw (No. 19 or 53) (see Fig. 46), through the vision box grating in the firing deck or by the stoker engine steam gauge, No. 31, which will vary between 15 and 25 pounds during normal operation. If a hard lump of coal or piece of foreign matter should check the speed of the stoker, the pressure in the engine cylinders will gradually increase until the engine has sufficient power to move the obstruction. If, however, the pressure rises to nearly boiler pressure and remains there it indicates that the stoker has stalled.

The stoker of today will fire a locomotive under all circumstances if properly manipulated. It is, however, not automatic; it depends upon human hands and intelligence for proper and efficient operation. The stoker will convey the coal fast or slow, depending upon the adjustment of the operating valve in the steam line to the stoker engine, and will distribute the coal to any part of the grates at the will of the fireman, depending upon his judgment in the manipulation of the distributing valves.

Light firing with constant distribution of the coal to cover entire surface of the fire bed will produce the highest combustion efficiency. Heavy firing or racing the stoker intermittently leads to improper and incomplete combustion, clinkered fires, excessive black smoke and waste of coal.

Handling of the grates in connection with stoker firing is an important factor. Grates should not be moved violently

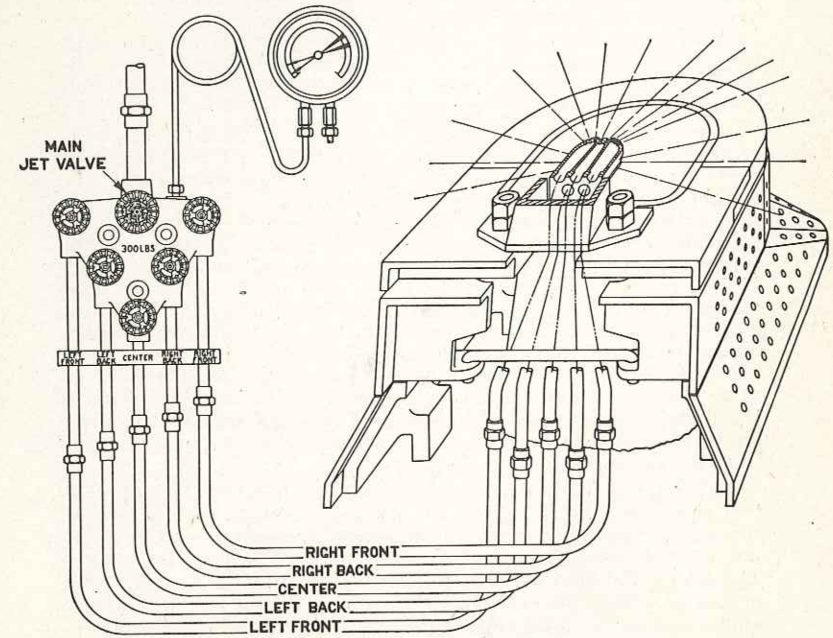
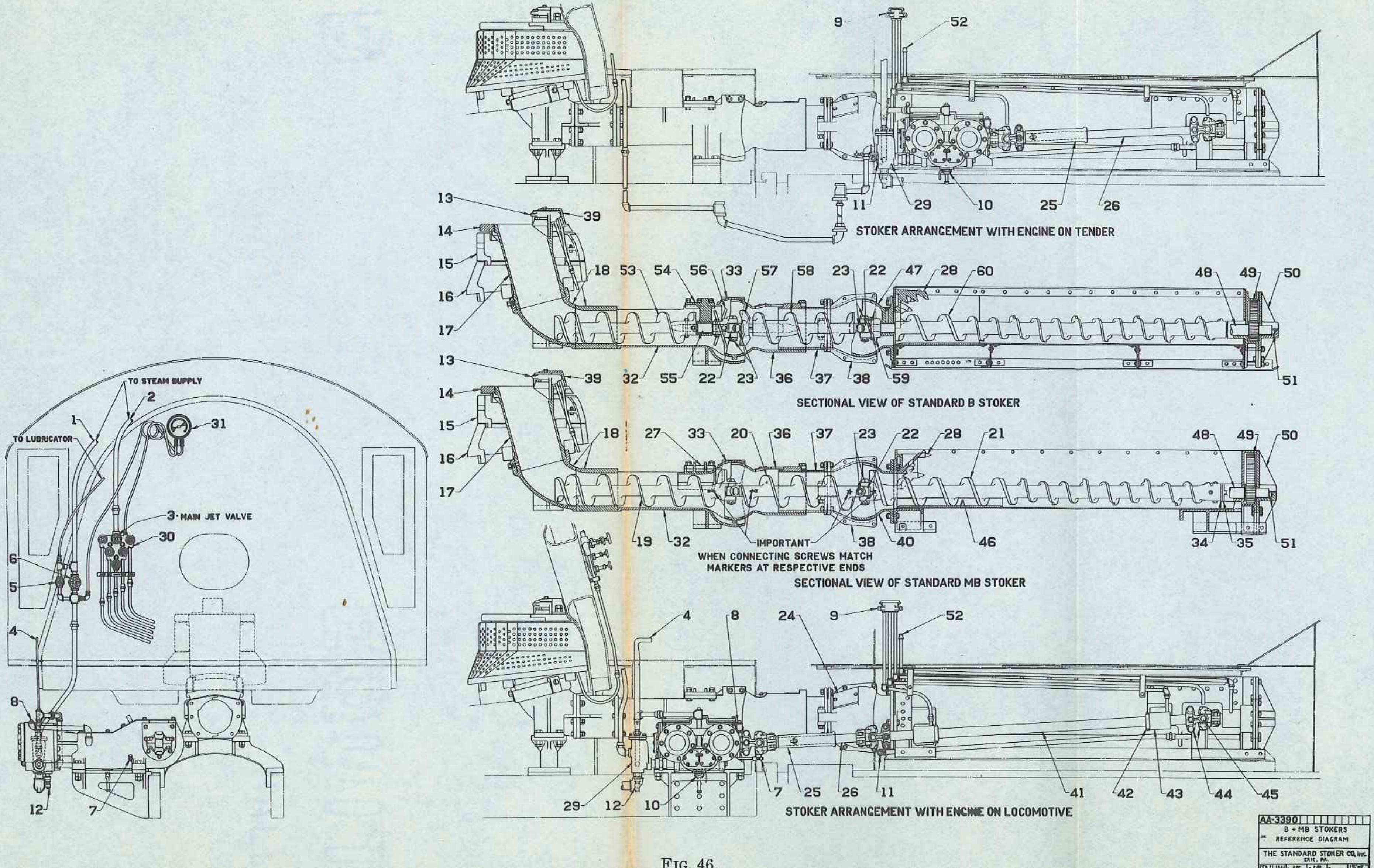


FIG. 47. Diagrammatic View of B or MB Stoker Distributor Jet and Manifold Piping Showing Location of Jet Holes.



TO STEAM SUPPLY
TO LUBRICATOR
3 · MAIN JET VALVE
STOKER ARRANGEMENT WITH ENGINE ON TENDER
SECTIONAL VIEW OF STANDARD B STOKER
IMPORTANT
WHEN CONNECTING SCREWS MATCH MARKERS AT RESPECTIVE ENDS
SECTIONAL VIEW OF STANDARD MB STOKER
STOKER ARRANGEMENT WITH ENGINE ON LOCOMOTIVE
AA-3390
B + MB STOKERS
REFERENCE DIAGRAM
THE STANDARD STOKER CO. Inc.
ERIE, PA.

FIG. 46.

while locomotive is working, on account of the light fire bed carried with the stoker. They should be moved lightly and as frequently as may be necessary, depending upon the type of grate in use, in order to keep the ash accumulation underneath the fire bed down to a point where it will not interfere with the uniform flow of air necessary to complete combustion. If it is necessary to shake the grates heavily to dispose of excessive accumulation of ash and clinker formation, it should be done while locomotive is standing or drifting, or at places where locomotive is worked light and the maximum boiler pressure is not required to handle the train. Holes in the fire are very apt to form from too heavy shaking of the grates while locomotive is working hard, and in many instances are the cause of steam failures before the fireman can locate the hole and stop the inrush of cold air.

Occasionally, conditions are encountered which necessitate readjustment of the distributing devices in order to maintain proper distribution of the coal. Some of these are: grade and weight of coal furnished, condition of coal, wet or dry; thickness of fire bed; change in the combustion rate or draft caused by change of cut-off. Irregular draft conditions through the grates caused by grates not being properly spaced and adjusted, improper setting of the brick arch and holes in the arch all have their influence on draft action and affect distribution. Therefore, occasional inspection of fire conditions and distribution is advisable. This will enable the fireman to take timely action to correct improper conditions that may be in the formative state and can be corrected by a slight readjustment of the distributing valves. Generally, if one adheres to the principles embodied in good hand firing, success in stoker firing will likewise prevail.

The engineer's handling of throttle and cut-off, which control the admission of steam to the cylinders, has its effect on successful performance of stoker-fired locomotives. Close cooperation between the engineer and fireman is very important. The fireman should be informed as to any movement out of the ordinary which imposes extra heavy work on the locomotive and requires special attention, particularly if he is not familiar with the road and operating conditions. The engineer should not start without asking the fireman if the fire is ready, as a light stoker fire is easy to upset when starting a heavy train. The locomotive should not be worked at longer cut-off just because the stoker will deliver coal and the pointer on the steam gauge registers the maximum pressure, but should be handled in the shortest cut-off possible to haul the tonnage and maintain the scehdule. Whenever the maximum output of the locomotive is needed, it can be had at all times, as all stoker-fired locomotives can be worked to capacity, the physical limitation of the fireman having no bearing on the efficient performance of the locomotive.

REMOVING OBSTRUCTIONS

If the stoker stalls, in nearly all instances an obstruction will be found at the crusher zone (located in the tender trough). To relieve it, reverse the stoker by placing the operating lever in reverse position. If, after repeated reversal, the stoker will not operate normally, it is an indication that the obstruction is too large to pass through the crusher.

IMPORTANT: When removing an obstruction from the conveying system be certain that steam valves are shut off tight and that the operating lever for the stoker engine is in neutral position.

To remove a clog at the crusher, reverse the stoker in the manner previously described, forcing the obstruction out where it can be removed from the conveyor. Should the clog be wedged so tightly that the stoker cannot be reversed, the crusher can be taken out by removing the two bolts which fasten it to the tender trough.

REVERSING VALVE

The reversing valve is an ordinary piston valve with inside admission and in normal operation steam passes from the boiler around the valve to the cylinder of the engine. In exhausting, steam passes out at the end of the valve to the atmosphere. In reverse position the reversing valve is pushed down (Fig. 48), permitting live steam to enter the exhaust steam chamber of the engine through the exhaust passage, the engine exhausting through the reversing valve to the atmosphere. It will be readily understood that this change of position of the reversing valve changes the engine valves from inside admission in normal operation to outside admission in reverse. Oil in the exhaust steam from the cylinders furnishes sufficient lubrication at all times for the reversing valve.

GENERAL SUGGESTIONS TO FIREMEN

The same general principles that pertain to fire conditions under hand firing apply to stoker firing, that is, to maintain a thin, level, bright fire and uniform distribution of fuel over the entire grate surface.

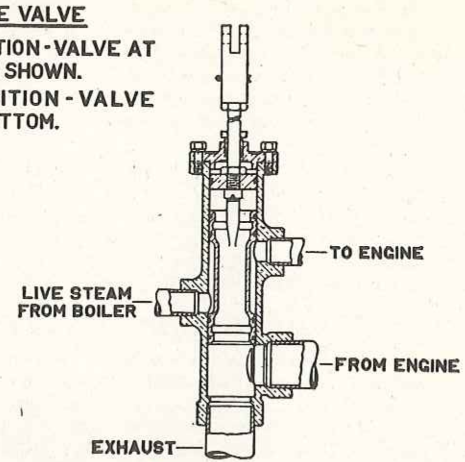
See that fire is clean and in good condition before leaving terminal.

Do not feed too much coal—carry a light fire. The stoker should be regulated to deliver a constant supply of coal to the firebox, but only enough to meet the demand on the boiler for steam.

Do not allow rock, iron, wood, or other foreign matter to be fed into the stoker if it can be detected in the coal and removed before it enters the conveyor.

Before taking coal, while en route or at terminal, see that all tank slides are closed.

See that the stoker is lubricated at recommended intervals.



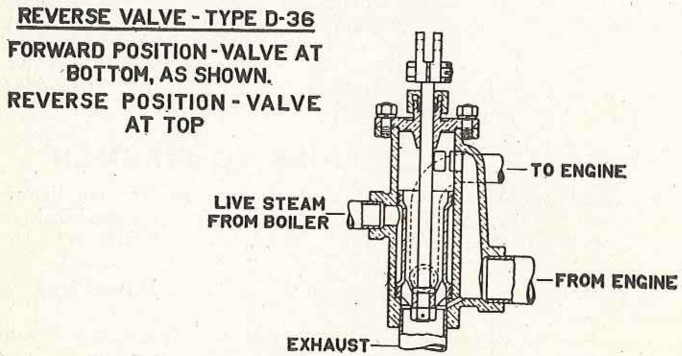


FIG. 48 Stoker Engine Reverse Valves.

TAKING COAL AND TERMINATION OF TRIP

Before taking coal en route all tender trough slides should be closed. They should also be closed before arriving at terminal and the stoker kept in operation for a short time thereafter, so that the conveyor may be empty on arrival. This is to prevent wet coal from freezing in the winter, also to permit roundhouse forces to make proper inspection.

Arriving at terminal, close stoker engine valve, and main jet valve. If the latter valve has not been provided with a bleed hole, it should be left slightly cracked until the fire has been dumped to guard against overheating of the firing table and to prevent the coal on top of vertical housing from catching fire. This same precaution should be taken when lying on sidings or drifting on long grades or at any other time when the stoker is not in operation.

Note condition of firing table, if burned or warped so as to affect distribution, report for replacement at terminal.

Report any other defect in stoker mechanism.

DESCRIPTION OF THE STANDARD TYPE FD STOKER

The Standard FD stoker introduces coal at the front end of the locomotive firebox immediately beneath the arch. The general construction of this stoker is shown in Figs. 49 and 50.

Like all Standard Stokers the tender unit of the FD Stoker consists of a trough rigidly secured to the tender underframe in a position to receive coal from the coal compartment. A gear reduction unit is carried by the rearward end of the trough and this reduction unit is connected by suitable flexible shafting to stoker engine. The usual telescopically flexible conveyor housing extends between the trough on the tender and conveyor housing on the rear part of the locomotive.

Instead of delivering coal into the firebox through that portion of the grates adjacent to the backhead, the FD Stoker employs a conveyor tube which passes beneath the grates and into the ash pan to a point short of the front waterleg of the firebox. An elevator housing is secured to the front waterleg and projects through the plane of the grates so as to open upwardly within the firebox. Thus, the coal delivery end of the FD Stoker is positioned adjacent the lower end of the arch.

The foremost end of the inclined elevator housing carries the distributor jet which directs radial jets of steam toward the sides, center and rear portions of the firebox grates.

A protecting grate surrounds that portion of the inclined elevator housing which is above the firebox grates. Air holes through the protecting grate serve to cool the latter and also provide secondary air over the fire bed.

Coal is conveyed forwardly from the tender by a conveyor screw consisting of a series of flexibly connected sections extending from the rear of the trough on the tender to a point within the inclined elevator housing at the front end of the firebox. The forwardmost screw section delivers the coal into the zone of action of the distributor jets which propel the coal across a firing table to all parts of the firebox grates. The upper surface of the firing table is inclined in rearward extent so as to compensate for the forward slope of the grates and to aid even distribution of coal over the firebed.

OPERATION OF TYPE FD STOKER

Instructions covering the operation of the type B and MB stokers apply to the type FD stoker, with exception that the operation is exactly the reverse from the rear delivery stoker, i.e., coal is delivered from the firing table towards the rear of the firebox, while with the rear delivery stoker the coal is delivered from the firing table towards the front of the firebox. This necessitates that steam jets should always be closed before the fire door is opened to read the fire, or for any other purpose, to avoid any possibility of hot burning coals being thrown out of the fire door and striking men in the cab.

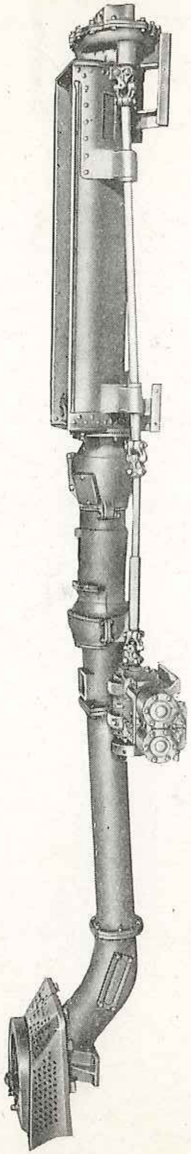


FIG. 49.
Type FD Stoker

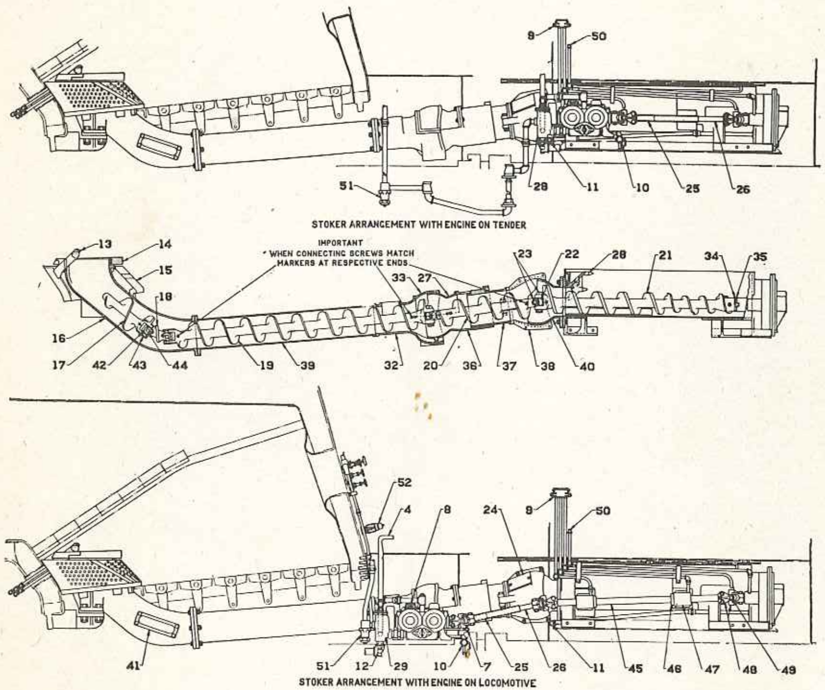


FIG. 50. Type FD Stoker.

POWER REVERSE GEAR

Modern locomotives are equipped with a power reverse gear which replaces the ordinary reverse lever for reversing the locomotive and controlling the valve gear.

The Ragonnet power reverse gear consists of a cylinder and piston connected by means of a reach rod to the valve motion. The reverse lever in cab operates the control valve which is located on top of the cylinder and is connected to the valve with a rod and a system of levers.

Pressure for operating the reversing piston may be taken from the main air reservoir, or steam pressure from the boiler may be used. When the reverse lever in the cab is moved into forward gear, a floating lever moves a control valve located in a valve chamber on top of the cylinder, admitting air to the proper end of the cylinder to move the piston in the proper direction to cause the valve gear to move to forward position. At the same time any pressure on the opposite side of the cylinder piston is exhausted to the atmosphere. As the piston moves the valve gear as described above, a connecting link which is attached to the piston rod crosshead, operates a combination lever which automatically carries the control valve to its central position, at which time the supply of pressure to the cylinder is cut off and the exhaust to the opposite end of the cylinder is also closed, thus stopping the piston if it has moved an amount corresponding to the movement of the reverse lever in the cab.

When the reverse lever in the cab is moved to the backward motion, the gear operates as described to set the valve gear for a backward movement of the locomotive. When the reverse lever in the cab is placed in its central position the piston in the reverse gear cylinder moves to the center of the cylinder, at which time the control valve cuts off the pressure, causing it to remain in that position.

It can be seen that a movement of the reverse lever either slightly forward or backward of its central position, causes a slight movement of the piston in the reverse gear cylinder, thus providing for moving the valve gear to a position corresponding to that of the reverse lever in the cab from full forward to full backward positions.

Before attempting to operate the reverse gear it should be known that ample air pressure is in the main reservoir and that the main reservoir valve, admitting air to the reverse gear valve chamber is open.

The cylinder is oiled through a lubricator or oil cup, located on the top of the reverse gear valve chamber, and all moving parts should be lubricated from the oil holes provided for that purpose.

A fountain valve is provided for shutting off steam from the boiler to the reverse gear. There is also a three-way valve in steam pipe located in the cab between fountain valve and reverse gear. When this three-way valve is sealed in closed position, steam is shut off to power reverse gear and drain is opened to atmosphere, to prevent steam or water passing to the reverse gear in case the fountain valve leaks.

If no air pressure is available, steam should be used to operate power reverse gear by opening the three-way valve and fountain valve located in cab. Steam should only be used in cases of emergency. Always report having turned steam on reverse gear so that cylinder packing may be given attention, and new seal applied to three-way valve in cab, because of breaking the seal when steam is applied to reverse gear.

Leakage from the cylinder around the piston rod causes a loss of pressure which is a continual drain on the main reservoir when the locomotive is working steam, and also tends to cause the gear to creep forward after the control valve has cut off the supply of air to the cylinder.

Leakage by the cylinder piston packing rings causes the air to leak from one end of the cylinder to the other, which, when the locomotive is working, causes a continual drain on the main reservoir and also causes the gear to creep after the control valve has cut off the supply to the cylinder.

Lost motion in the pins connecting the combination lever and also lost motion in the valve stem, either where connected to the slide valve or at the combination lever, requires additional movement of the combination lever to cause the control valve to close the ports after the reverse lever is placed in any position. Such lost motion causes the gear to creep without a loss of air pressure, unless there is excessive lost motion in which case the gear may creep far enough so that when the control valve opens a return movement to its original position may cause the control valve to open the exhaust port.

Locomotives equipped with power reverse gear must not be moved under their own power unless air or steam is applied to the reverse gear under sufficient pressure to insure proper operation of the gear.

Locomotives with valve gears connected, that are to be moved by power other than their own, where air or steam is not supplied to the reverse gear under sufficient pressure to insure proper operation of the gear, must have valve gears of reverse gear blocked so that crosshead of reverse gear cannot move. This rule applies to locomotives moved at shop and terminals as well as on the road.

Fig. 51 shows a sectional view of the type "A" gear and ports leading from each end of the control valve directly to ends of cylinder. Some types of the gear have these ports crossed so that the port from one end of the valve leads to the opposite end of cylinder.

The type "B" gear, works on the same principle, as the type "A" the slide valve being operated by a rocker arm passing through the side of the valve chamber.

The names of parts corresponding with numbers in Fig. 51 are as follows:

3. Crosshead
4. Crosshead Pin
5. Cylinder
6. Guides
7. Combination lever and Rocker Arm Pins
8. Piston Bullring
9. Piston Packing
10. Piston and Rod
11. Piston Rod Gland & Ring
19. Control Valve & Stem
20. Valve Stem Gland Ring
21. Valve Stem & Guide

This company has in service other types of power reverse gears which operate on practically the same principle as the Ragonnet Gear.

The Baldwin power reversing gear operates on the same principle as the Ragonnet type A or B, except that air or steam is delivered to either end of cylinder through a rotary valve instead of a slide valve as shown on Fig. 52.

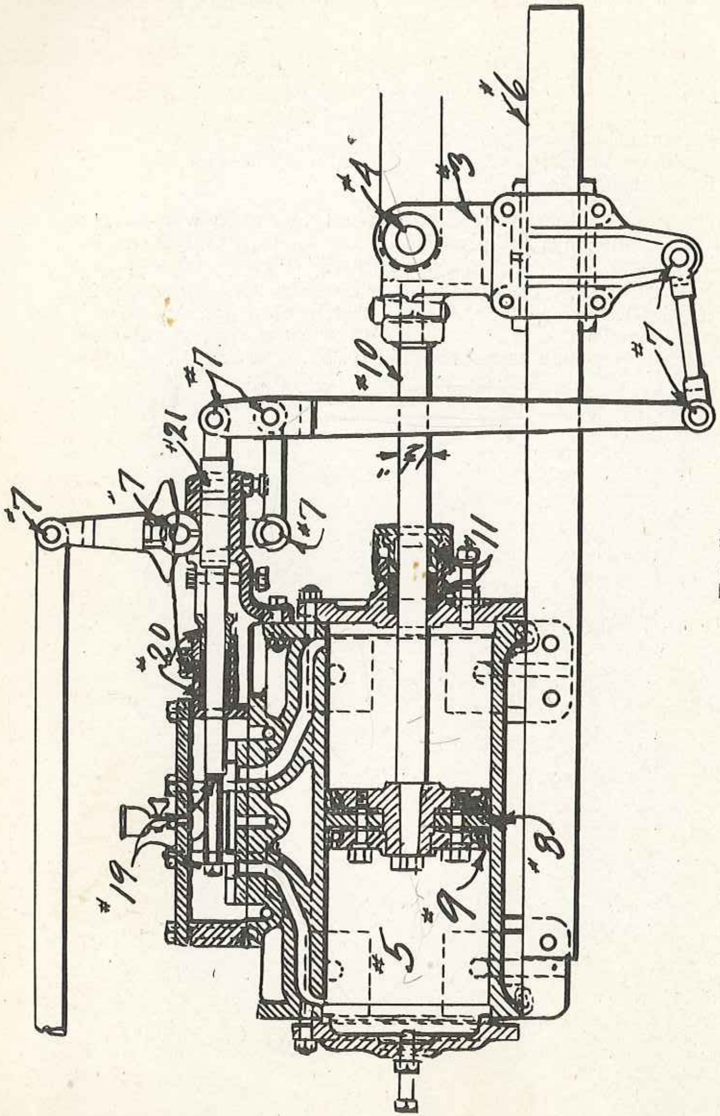


Fig. 51.

Type "A" Reverse Gear Cylinder and Valve Arrangement.

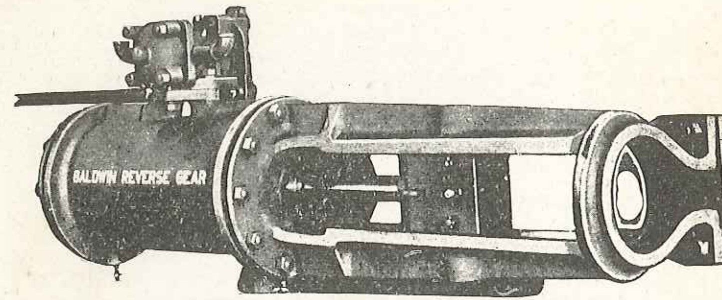


Fig. 52.

Baldwin Reverse Gear Cylinder and Valve.

CAB STEAM HEAT SYSTEM

In order to provide for the comfort of the engineer and fireman during cold weather, locomotive cabs are equipped with an independent system of steam heating pipes or coils. The steam heat pipes or coils are located on the running board under the engineer's and fireman's seat boxes. Connected into the blower steam pipe is a branch pipe leading to a small reducing valve which controls the pressure admitted to the heating coils. A globe valve is located in this branch pipe between the blower pipe connection and the reducing valve to enable the steam to be closed off from the steam heat system.

Leading from the reducing valve is a steam pipe connected to the steam heat pipes or coils on each side of the cab. These two connecting pipes are equipped with globe valves in order that steam may be used in the coils at one or both sides of the cab, as desired, or that the steam may be closed off from the coils on both sides. After the steam passes through the heating coils it is admitted into a steam trap or condensor, in order that the steam will be condensed into water, to prevent as far as possible any steam being passed to the atmosphere which might tend to cause steam clouds around the cab.

A small steam gauge, located in the cab, indicates the pressure carried in the steam heat coils. This pressure should not exceed twenty-five to thirty pounds. To increase the pressure loosen the jam nut and screw down on the adjusting stem located at the top of the reducing valve. To reduce the pressure screw upward on the stem. After the proper adjustments have been made the jam nut should be tightened.

If a heavy flow of steam is had at the steam trap under the cab, the steam trap is not working properly and should be reported for repairs. There should be a very little or no steam showing at the trap when it is operating properly.

For instructions on steam heat for trains see "Instructions for the Operation of Passenger Car Heating and Water Distribution," issued by this Company.

POWER GRATE SHAKER

The power grate shaker, which is provided to reduce the labor of the fireman, consists of an operating valve and cylinders. The operating valve is located on the boiler head at the left side of the cab. A steam pipe connection supplies steam from the boiler to the operating valve. A globe valve is applied in this steam pipe to close off the steam supply from the boiler. The cylinders for shaking the grates are located under the cab deck; the pistons are connected to suitable levers extending inside the cab for the purpose of connecting the cylinders to the grate shaker levers. Steam pipe connections lead from the operating valve in the cab to each end of each cylinder, for the purpose of supplying steam for moving the pistons in such cylinders. A small lubricator is mounted on the operating valve body, or in the steam supply pipe leading from the boiler to the operating valve, for the purpose of lubricating the operating valve and cylinders. The lubricator should be filled each trip and opened when steam is supplied to the operating valve.

To operate the grate shaker see that the shaker bar is removed from the shaker post which operates the section of grates to be moved, throw back the lock holding such shaker posts, throw in the lock on the center post to connect the shaker post at either side to the center post, turn on steam in the supply pipe to the operating valve and open the lubricator; then move the handle on the right side of the operating valve, if the grates on the right side of the firebox, or on the left side of the operating valve, if the grates on the left side of the firebox are to be shaken. Moving the handle forward causes the shaker post to also be moved forward, the same as when using the shaker bar. Moving the handle backward causes a backward movement of the shaker post. Moving the operating valve to its central position shuts off steam to both ends of the shaker cylinders.

Do not move the handles on the operating valve back and forth too quickly. Move the handle to either the forward or backward position and watch the shaker post, to note whether the cylinder has moved the shaker post to a position corresponding to that of the handle on the operating valve, which it should do. If no movement is observed, the handle should be reversed to the op-

posite position, allowing the shaker cylinder to move the grate shaker post in the opposite direction. Move the handle of the operating valve back and forth only as fast as the cylinder is able to move the shaker posts. If the handle is reversed too quickly no movement will be had from the cylinders.

There are two cylinders, one for the section of grates on the left and one for the section of grates on the right. The operating valve has two handles, the handle on the right operates the cylinder and grates on the right side of the firebox, and the handle on the left operates the cylinder and grates on the left side of the firebox.

After using the power grate shaker, see that locks for holding the shaker posts in central position are in place and the shaker posts are locked. The locks for holding the shaker posts in position are composed of two parts. If it is desired to move the grates slightly throw out the center part of the lock, this will provide for a slight back and forth movement of the shaker post. When full movement of the grates is desired, throw out both parts of the lock, thus providing for full travel of the shaker posts.

Never attempt to operate the power grate shaker and the shaker bar at the same time. To do so may cause injury to the person attempting to handle the shaker bar.

After using the power grate shaker, shut off the valve in the steam supply pipe to the operating valve and the lubricator. Do not have steam supply valve to operating valve open when shaking grates by hand with the shaker bar.

DESCRIPTION AND INSTRUCTIONS FOR OPERATING THE STEAM COAL PUSHER

The steam coal pusher, designed to eliminate the necessity for the fireman shoveling the coal forward in the tender is shown in Fig. 53, located in the coal pit of an ordinary tender. It will be noted that a steam cylinder is fastened at the top of the slope sheet of the coal pit. Attached to the piston of this cylinder are two crossheads which act to push the coal forward. These crossheads rest at the bottom of the coal pit and when steam is used, the cylinder forces the crossheads forward toward the coal gates, thus pushing the coal forward at the bottom of the pit. This tends to mix the fine coal with the lumps and prevents an accumulation of very fine coal at the bottom of the coal pit.

Before starting on trip the coal pusher lubricator, located in the steam supply pipe in the cab, should be filled with valve oil. Do not use engine oil in this lubricator.

The pusher should be allowed to make a couple of strokes before lubricator is opened up. This in order that the piping and cylinder may be warmed up. To open the feed on lubricator, close globe valve in steam line from turret, then open the small globe valve above and below the lubricator, then reopen the main steam valve. When pusher is not in use the lubricator should be shut off.

Open globe valve in steam line slowly to allow condensation to work out through the drain valve. Then move operating handle to place the operating valve in its lower or back position, holding this position of the handle until the pusher completes its upstroke this movement loosening the coal around the pusher member as it rises, after which let go of the handle and the operating valve automatically returns to its upward or forward position causing the pusher to make its downward or pushing stroke. The main steam valve should be closed when pusher is not in use in order to allow the drains to remain open and free the piping from condensation.

Coal pushers are to be tested at terminal after each trip. Enginemen should test the coal pusher by operating it before leaving locomotives on arrival at terminals. If the coal pusher fails to work properly, make necessary report so that repairs can be made before tender is filled with coal.

PNEUMATIC SANDERS

The pneumatic sander is designed to provide for placing a continuous stream of sand upon the rail to prevent locomotives slipping. A system of pneumatic sanders is installed to each side of the locomotive. A sand dome is applied on top of the boiler to carry the sand supply. Some locomotives have two sand domes. The location of sand dome is such that the heat from the boiler tends to keep the sand dry after the sand dome is filled.

Suitable pipe connections at each side of sand dome lead to the rail for the purpose of delivering sand to the driving wheels for either forward or backward motion of the locomotive.

Installed in the sand delivery pipes leading to the rails, is what is called a "sand trap." These sand traps are equipped with small nozzles, and pipe connections lead from the main reservoir, through the cab, and connect to the sand traps in such a manner that as air pressure is passed from the main reservoir to the sand traps the air passes through the small nozzle, blowing a jet of air into the sand delivery pipes. The sand from the sand box flows to the sand traps by gravity and is then blown into the delivery pipes by the air passing through these nozzles. As long as air is admitted to the nozzles and sand flows from the sand box, a continuous stream of sand will be spread upon the rails.

Various types of engineer's valves are used for the purpose of admitting air from the main reservoir to the sand traps. Some of these valves are so arranged that when they are open air is allowed to blow through a small hole in the valve body, which makes sufficient noise to attract the engineer's attention when the valve is in open position. Such openings are called "warning ports," and are provided for the purpose of attracting the engineer's attention, so that he will not leave the operating valve open unintentionally.

In some cases the sand operating valves are of such construction that moving the handle forward operates the sanders leading to the go ahead sand pipes and moving the handle backward operates the sanders leading to the back-up sand pipes.

Some of these valves are designed along the lines of the ordinary plug cock, while others are of the rotary valve type. Leaving the valve open unnecessarily causes a waste of air and also a waste of sand, in addition it increases the difficulty of pulling a train if a heavy layer of sand is spread upon the rails continuously.

In the "Graham-White Sander," an additional air connection is made from the engineer's operating valve to the sand trap. This additional air supply pipe is for the purpose of blowing a current of air through the sand delivery pipes through a much larger opening than provided in the sanding nozzles. The object being to clear the delivery pipes of wet sand or other obstructions, in case such obstructions exist. When sand becomes wet it packs and will not flow freely. Sometimes moisture accumulates inside the sand pipes near the bottom, and when using the sanders the sand tends to stick to the inside of the pipes at this point. If this condition continues, the sand will gradually pack in the pipe until the pipe is stopped up, when it is necessary to tap the pipe sufficiently to dislodge the wet sand and cause it to fall out of the pipe. If, however, a large volume of air under heavy pressure is admitted to the sand trap, the wet sand can usually be blown clear of the pipe, permittting proper operation of the sander when air is admitted to the sanding nozzles.

The improved Graham White sander operating valve shown in Fig. 54 is of the poppet valve type and that the one valve handle operates both the forward and backward motion sanders, and the blow out.

When the handle is moved about midway of its travel in either direction it opens the valve to admit air to the blow out pipes as well as the operating pipes. When moved to its extreme or operating position, the port leading to the blow-out pipe is closed by the piston section of the valve stem and in this position air is allowed to flow through the operating pipe only.

When moved to its extreme position, either forward or backward, the handle latches in open position. To unlatch the valve it is necessary to push down on latch rod in upper end of handle when the spring beneath the valve will return handle to closed position.

In using the sanders move the valve to the blow-out position momentarily, or for just a few seconds, then move the handle to its sanding position. Do not leave the handle in the cleaning or blow-out position except momentarily. The pipes and passages leading from the main reservoir are quite large and if the handle is left in cleaning position too long, the main reservoir pressure will be reduced, which might cause a loss of excess pressure, which would cause the brakes upon the locomotive or train to apply.

Report all leaks observed in the air pipes leading to the sanders, and also any leaks which will permit moisture to enter

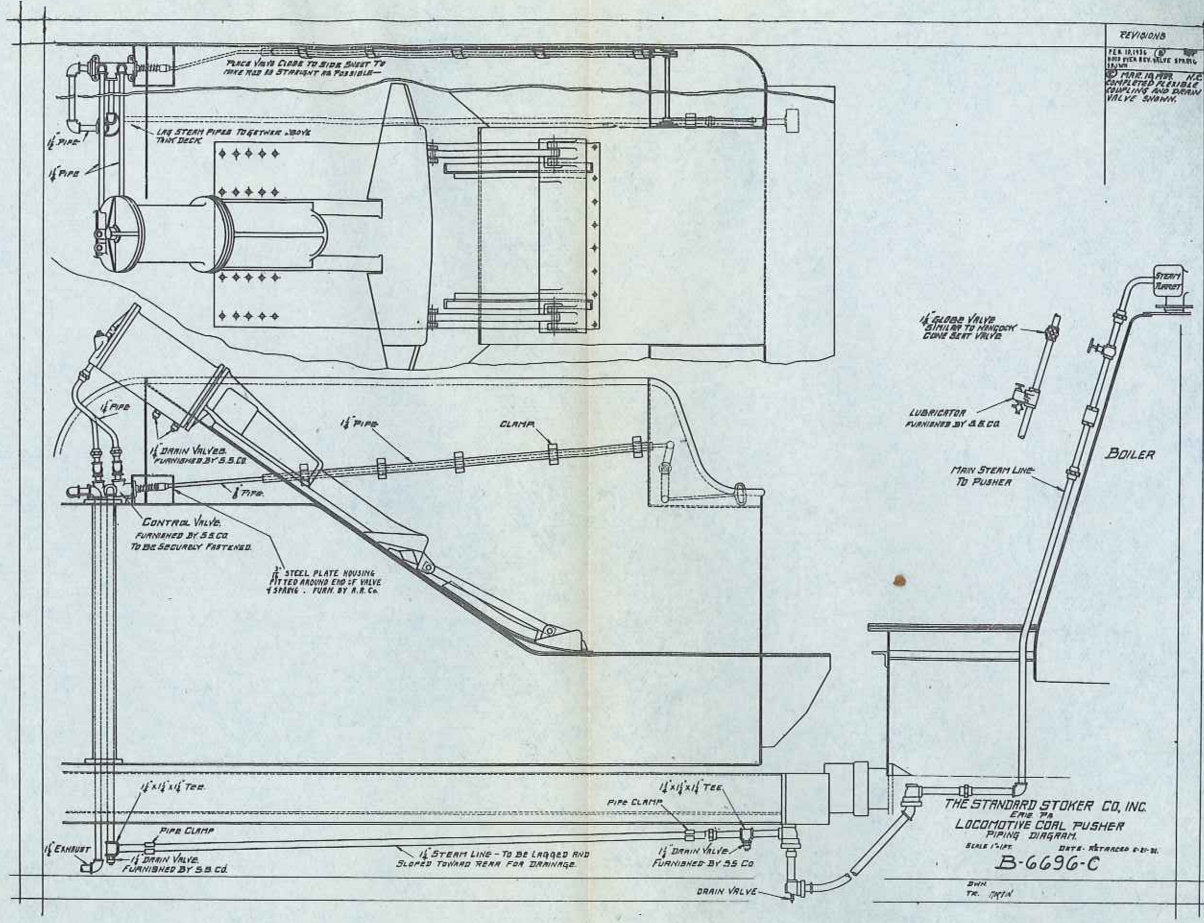


FIG. 53. Type D-A.

the sand box or the sand traps. Usually leaks around the sand box and sand traps will be evidenced by signs of sand or sand dust at such places. When this is observed report promptly, so that repairs can be made to prevent moisture entering the traps or sand box, which might cause the sand to become wet and packed, interfering with the proper operation of the sanding devices.

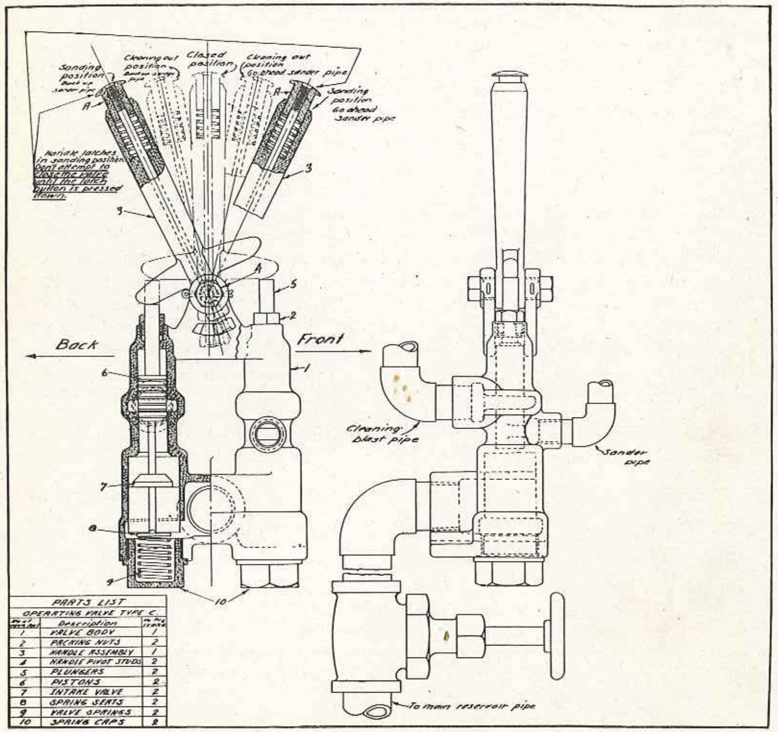


FIG. 54. Sander Operating Valve.

PNEUMATIC FIRE DOORS

To relieve the fireman of the labor of opening and closing the swinging fire door, automatic fire doors are applied, the doors are operated by compressed air. A small cylinder is provided to operate the door, the piston of such cylinder transmits mo-

tion to the fire door by means of a link or lever. In most cases the fire door consists of two parts, and a link or lever connects to each section of the door, which provides for both sections opening in unison.

A foot pedal, located so as to just clear the cab floor, is placed in such position as to be convenient for the fireman to operate with his foot, when standing in his usual position for firing the locomotive. To operate the door press down on the foot pedal, which raises a valve from its seat, admitting air from the main reservoir to the operating cylinder. This moves the piston in the cylinder, causing the door to open. To close the door release the foot pedal, the supply of air from the main reservoir is then cut off from the cylinder and the air in the cylinder is exhausted allowing the door to close.

The door should be closed after each scoop of coal is applied to the firebox.

Oil the various pins connecting the rods and levers once each trip. The cylinder should be oiled through the oil cup, and the pins and levers oiled through oil holes provided for that purpose.

Provision is made by applying an adjustable choke in the exhaust passage leading from the operating cylinder so that the pressure will be exhausted from the cylinder at such a rate as will prevent the doors closing suddenly and striking each other with considerable force. When it is noticed that the doors do operate in this manner report should be made so that proper adjustment of the choke can be made to provide for the doors closing gently.

FLANGE LUBRICATOR MANUAL

Since the flanges upon the wheels are the only means of maintaining; a locomotive or car in place on the track, or guiding same around curves, it is obvious that they and the rails are both subject to wear when these two surfaces come into contact with each other.

The main frames of a locomotive are not permitted to turn under the boiler in the same manner as is common to the ordinary two, four or six wheel truck, and it therefore requires a greater effort on the part of the flanges on the driving wheels to guide the locomotive, than is the case with the truck wheels at either end.

A large per cent of the guiding effort is produced by the leading trucks and trailing trucks upon the locomotive, but notwithstanding this, such trucks are free to turn or move from side to side, while any side movement of the driving wheels cannot be transmitted to the main frames, in the same manner as is common to the leading and trailing trucks. The flange wear is therefore greater than is common to the smaller size wheels used in the ordinary truck.

To reduce the wear of the driving wheel flanges and also the inside edges of the rails, flange oilers are applied. The flange oiler is constructed on the same principle as the hydrostatic lubricator which is used to lubricate the main valves in the steam chests or valve chambers. This flange oiler is located in the cab, on the left side of the boiler head. Suitable pipe connections lead from the flange oiler to the driving wheels that are to have the flanges lubricated. Nozzles are applied at the end of these pipes to direct the oil to the throat of the flange. This provides for placing a coating of oil on the flange as the driving wheels revolve.

The flange oiler consists of an oil bowl, which holds about one quart of oil. Above the oil bowl is a condensing coil. Steam is admitted from the boiler into the condensing coil, and at the same time passes around the condensing coil to each side of the lubricator, where it connects to the delivery pipe connection leading to the driving wheels at each side of the locomotive. Above the point where the oil delivery pipe connects to the lubricator, is a sight glass, and just above this point is located a feed valve. The connection to the feed valve leads inside of the lubricator bowl and is piped to the top of the bowl. At the bottom of the condensing coil a valve is located, which permits water from the condensing coil to pass to the bottom of the oil bowl.

As steam enters the condensing coil it has no means of circulating through the lubricator. It consequently condenses into water. This water is passed beneath the oil in the oil bowl, causing the oil to raise on top of the water, where the oil flows into the pipe which conducts the oil to the feed valves. When the feed valves are opened the oil is permitted to flow through the feed valve, where it drops past the sight feed glasses into the current of steam flowing through the oil delivery pipes. The current of steam which is flowing out through the delivery pipes carries the oil with it to the nozzles located close to the flanges, where the oil is blown upon the flange by the current of steam The nozzles should be located close to the flanges and directed so that the oil will be blown upon the flange and not upon the tread of the wheel.

A steam valve, located in the steam pipe leading from the foundation to the condenser, permits of shutting off steam to the flange oiler. The valve located below the condenser permits of shutting off the flow of water from the condenser to the oil bowl. The feed valves located above the sight feed glasses permits of shutting off oil from the flange oilers to the delivery pipes. A drain valve located in the bottom of the lubricator provides for draining the water out when it is desired to refill the oil bowl, and a filling plug at the top is provided for refilling the bowl.

The flange oiler is illustrated in Fig. 55.

LIST OF PARTS MANUALLY OPERATED FLANGE OILER

34. Drain valve for oil bowl
35. Steam connection
69. Packing nut for glass
70. Follower ring and washer for glasses
80. Solid glass for sight feed
89. Gaskets for solid glasses
185. Oil bowl
189. Feed Valve
191. Condenser valve complete
193. Filler plug
194. Feed tips
197. Flange nozzle
198. Steam pipe choke
201. Choke for oil delivery pipe
292. Steam valve

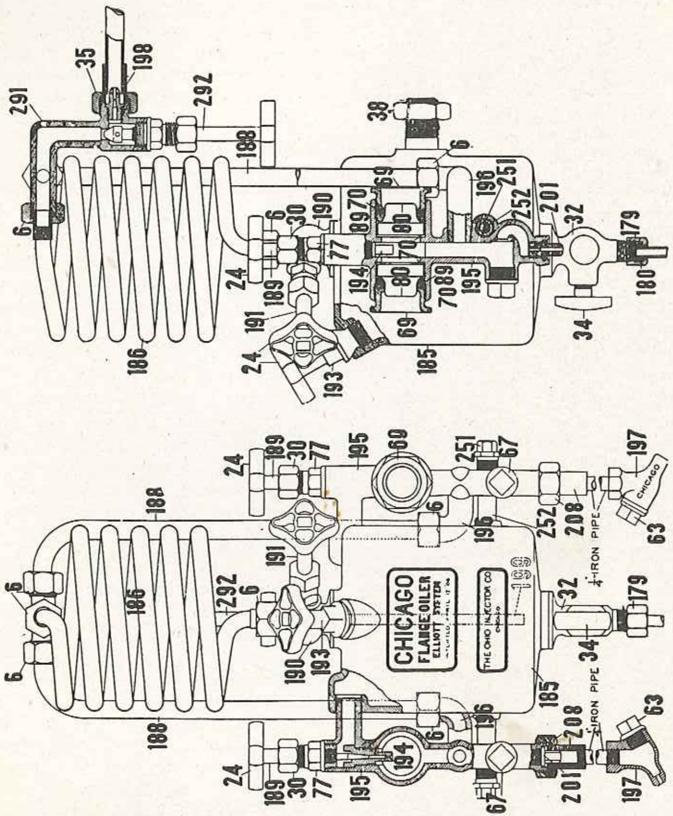


FIG. 55.
Two Feed Manually Operated Flange Lubricator.

TO OPERATE FLANGE OILER

To Operate—Open steam full at boiler. Open steam valve 292 three full turns. Open condenser valve 191 three turns, then regulate feed of oil with feed valves 189.

To Fill Oil Bowl—First, close all feed valves (189). Second, close condenser valve 191. Third, close steam valve 292. Fourth, open drain valve plug 34, and then carefully remove filler plug 193. When oil bowl is drained, close drain valve plug 34, and fill the bowl with oil.

Rate of Feed—Oil should be fed at the rate of 12 to 15 drops per minute, or faster, as required, to keep the flanges thoroughly coated. Let the flange be the indicator and regulate feeds accordingly.

When Starting on Run—Open main steam valve at least 15 minutes before setting the oil feeds, and when finishing the run, shut off the oil feeds 189 and condenser valve 191, leaving steam on to clean out the delivery pipes, thus preventing stoppage and freeze-ups. In cold weather be sure and leave steam turned on at all times when locomotive is not in the roundhouse.

Too Much Steam—If too much steam appears at the flange nozzles, have the steam choke 198 renewed. Do not try and regulate the steam supply with the steam valve 292, as this practice will contribute to stoppages.

To Clean Flange Nozzles 197—Remove cap 63 and run a wire through the opening; then turn on the steam and blow out pipes.

Adjustment of Flange Nozzles—If the lubricant is delivered to the tread of wheel, it indicates improper adjustment of flange nozzle 197. Adjust this nozzle to deliver the lubricant into the throat of the flange without putting any lubricant on the tread of wheel.

Cleaning Feeds and Sight Feed Glasses—First, close condenser valve 191, then open drain valve plug 34, and drain oil bowl. Leave the drain valve open, then open feed valves 189, one at a time, permitting steam to pass back through the feed pocket and feed tips into the oil bowl and out through the drain.

THE AUTOMATIC FLANGE OILER

A sectional view of the Automatic Flange Oiler is shown in Fig. 56.

Steam entering through Steam Pipe Choke No. 198 flows through Steam Pipe Tee Connection No. 376 and Steam Circulating Pipe No. 188, fills the Sight Feed Pocket and flows downward through Delivery Pipe Choke No. 201 to point of delivery.

At the same time steam pressure plus weight of condensate in the Condenser Coil No. 186 is applied through Condenser Valve No. 352 (when open), through Water Pipe No. 199 and

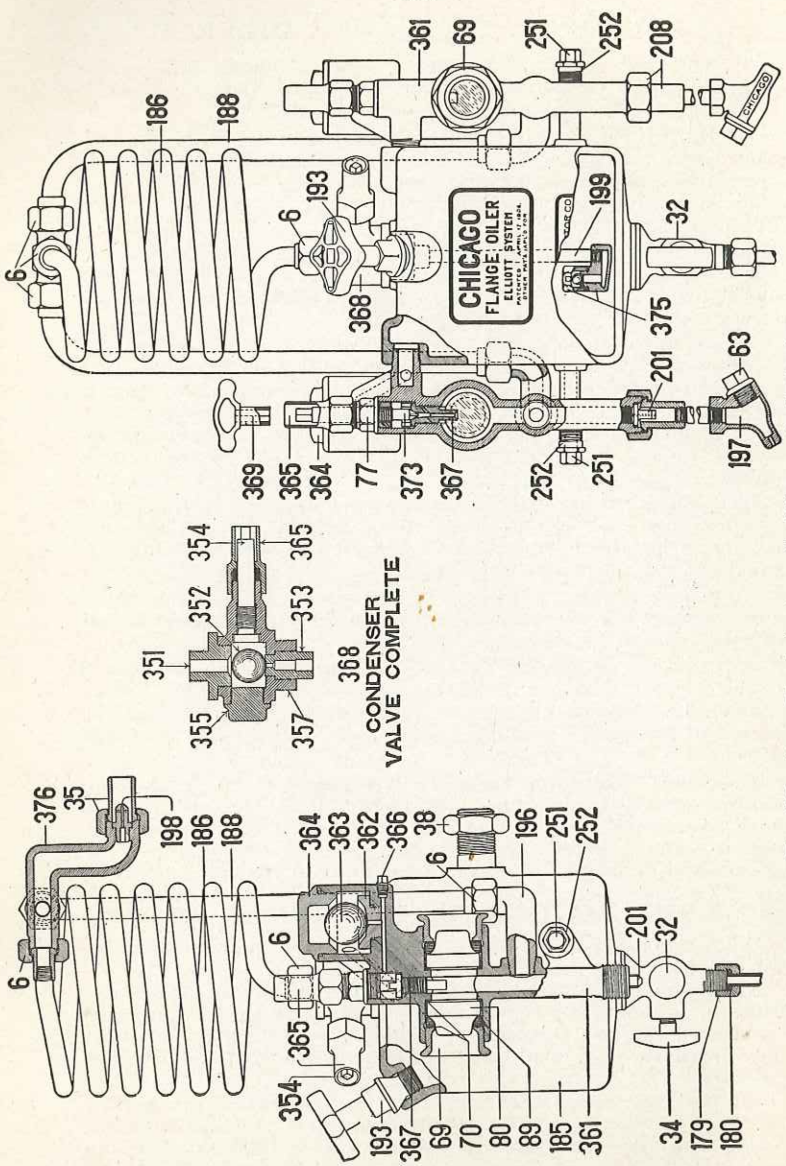


FIG. 56. Two Feed Automatic Flange Lubricator.

Check Valve No. 375 to the water and oil in the Oil Bowl. The oil under pressure is raised to the Feed Pocket controlled by the Ball Feed Valve No. 363.

Ball Feed Valve No. 363 operates on a 6-degree dished seat. When the locomotive is running the ball rolls off its seat, due to the motion of the locomotive, opening the feed port as shown in the cut and permitting the oil to feed through the feed port, by the V-shaped groove on the Feed Valve No. 373 and through the Feed Tip No. 367 into the Sight Feed Pocket. When the locomotive stops the ball moves by gravity to the bottom of its seat and closes the feed port.

Condenser Valve Ball No. 352 also operates on a 6-degree dished seat and when not held open by Condenser Valve Stem No. 354, operates automatically, rolling off its seat to open when the locomotive is running and moving by gravity to close when the locomotive stops. To insure an uninterrupted feed pressure on the oil the oiler should be operated with the Condenser Valve wide open as shown in the cut.

Feed Valve No. 373 has a small V-shaped groove the full length of the point of the valve. This is the by-pass for the oil to feed through. When the feed valve is set, it has a fixed opening that permits a certain quantity of flange oil to feed, regardless of the speed or track conditions. The operating position is with the feed valve screwed down on its seat.

HYDROSTATIC LUBRICATOR

In order to provide for lubricating the main valves in the steam chests or valve chambers continuously, while the locomotive is working steam, a main lubricator is located in the cab. Fig. 57 illustrates the five-feed lubricator in common use. It will be found that some locomotives are equipped with a three-feed lubricator, the operation of which, however, is identical with that of the five feed.

List of Parts

9. Steam connection
23. Filler plug
31. Feed valve for pump
33. Drain valve
34. Drain valve plug for oil bowl
62. Pressure valve
65. Auxiliary oil cup
66. Auxiliary oil cup filler plug
69. Packing nut for glass
70. Follower ring and washer for glass
73. Water valve
78. Auxiliary oil cup feed valve (run closed when not in use)
80. Solid glasses, sight feed or index
88. Auxiliary oil cup drain valve
89. Gaskets for solid glasses
175. Low pressure feed valve
176. High pressure feed valve

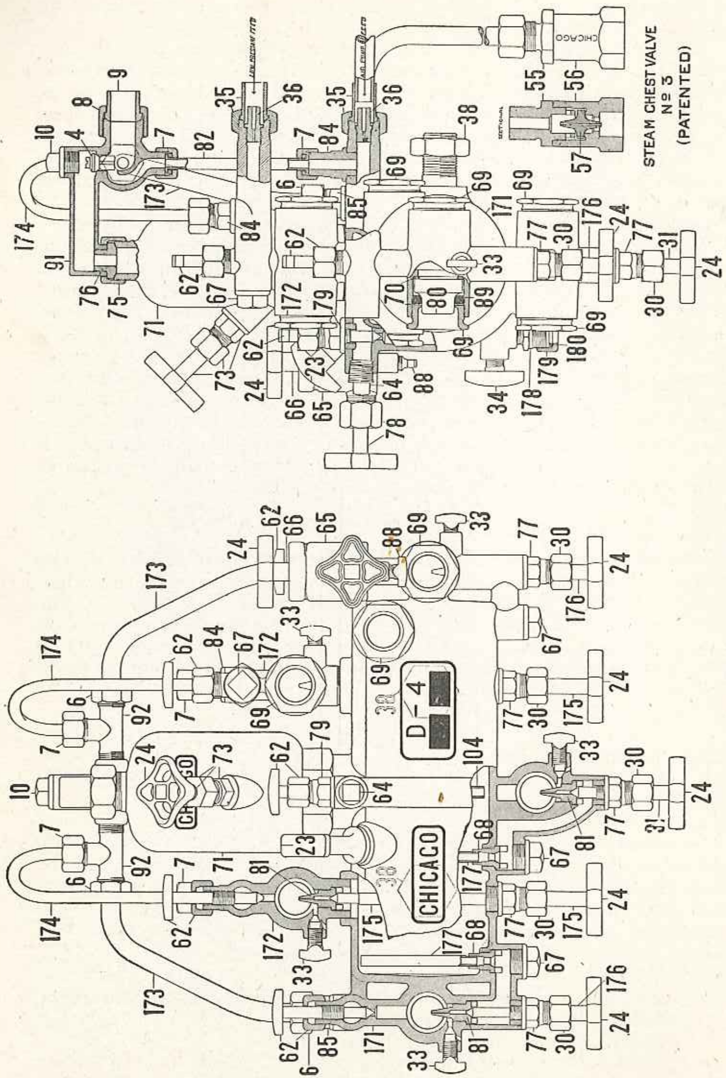


FIG. 57. Five Feed Hydrostatic Lubricator.

The principle of operation of the lubricator is as follows:

The central portion or body 171, of the lubricator is an oil bowl with a capacity of three or five pints. Above the oil bowl is located another small bowl or condensing chamber 71. A steam pipe connection connected at 9 leads to a connection at the top of the boiler. Steam is therefore admitted to the condensing chamber through connection 9, past check valve 4 and through pipe 91 to the condensing chamber 71. Since there is no circulation of steam from the condenser 71 through the lubricator, any steam passing into the condenser is condensed into water. When valve 73 is open, water from the condenser is permitted to pass through pipe 104 to the bottom of the oil bowl or reservoir 171. Any oil in the oil bowl is therefore raised on top of the water to the top of the oil bowl and flows down pipe 177 to feed tips 81. It will be noted there is a feed tip 81 located on top of the oil bowl, oil is therefore caused to flow to all these feed tips 81. At the same time steam passes through pipes 173 and 174 to the top of the sight feed glass chamber at valve 62, where it passes out through the connection 36, then through choke valve 56 and to the steam chest or valve chamber. When valves 62 are open steam is also admitted to the space above the feed tips 81 between the sight feed glasses. As there is no circulation of steam in the chamber above the feed tips, this space also fills with water. Solid sight feed glasses are provided through which the feed tips 81 may be plainly seen.

With the lubricator filled with oil and valves 73 and 62 opened, and the main valve open at steam pipe connection 9 at the fountain, the lubricator is ready to start.

Since the condenser 71 is full of water, and this water is passed through pipe 104 under the oil in the oil bowl, the oil has been raised up on top of the water to the feed tip 81. When valves 175 and 176 are open the oil is forced through the feed tip 81, where it rises through the water in the form of drops of oil, which can be plainly seen by looking through the sight glasses 80. The oil rises through the water in the sight glass chambers where it passes through the oil pipe connections 35 and choke 56 to the steam chests.

As the oil is fed out of the oil bowl 171, water passes down from the condenser 71 which continues to raise the oil in the oil bowl. When valve 31 is open oil is fed through feed tip 81, through choke 36 and pipe connection leading to the air pump.

The choke 56 is connected in the oil delivery pipes close to the steam chest or valve chamber. The opening through this choke valve being very small permits a light flow of steam through the oil pipe, sufficient however, to properly deliver the oil to the steam chest. At the same time it maintains the same pressure in the oil delivery pipe between the choke valve and the lubricator as is carried on the lubricator. In this way the pressure of steam on the water in the sight glass chambers and in the condenser is balanced. The condenser being above the oil bowl provides for the weight of the water in the condenser raising the oil in the oil bowl. The light flow of steam through the oil pipe provides for sufficient circulation to assist in carrying the oil from the lubricator to the valve chambers and cylinders.

TO OPERATE THE HYDROSTATIC LUBRICATOR

Open steam valve full at boiler. Open valves 62 (Fig. 57) one turn. Open water valve 73 three turns. Note the feed glasses to see if filled with condensation. After the glasses are filled regulate feeds with valves 31, 175 and 176.

To blow out glasses: Close feed valve 31 or 175 or 176 and pressure valve 62; open valve 33 to exhaust pressure, after which regulate flow steam through glass with valve 62.

To fill glasses with water: Close valve 33 and open valve 62 one turn.

To operate auxiliary oil cup 65, close pressure valve 62. See that valve 78 is closed. Open auxiliary drain valve 88 to free cup of water. Open auxiliary filler plug 66 and fill. After cup is filled close cup tight and open feed valve 78 wide. One filling of auxiliary oil cup will feed one hour. This auxiliary cup can be operated with steam on lubricator and engine throttle open.

To remove gaskets or glasses with steam pressure on lubricator: Close valve 62; open valve 33 to drain, then remove packing nut 69, follower washer 70, and gasket 89 with small packing hook. After gasket is removed glass will come out.

To drain lubricator when drain valve No. 34 is broken off:

1st—Close all feed valves Nos. 31 and 176.

2nd—Close water valve No. 73.

3rd—On left side of lubricator, close pressure valves No. 62 over low pressure feed pocket and valve (high pressure) feed pocket. Next open drain valves No. 33 on each of these feed pockets.

4th—Open feed valve No. 176 to exhaust pressure from top of oil bowl. Leave feed valve open until all pressure is exhausted.

5th—Next, on left side of lubricator remove packing nut No. 30 and feed valve No. 175. This drains all water and oil from lubricator oil bowl.

6th—Remove filler plug No. 23; replace feed valve No. 175 and fill lubricator full. Replace filler plug No. 23 and start lubricator in regular way.

To fill lubricator when filler plug No. 23 is broken off in oil bowl:

1st—Close engine throttle; close lubrication; close all lubricator feeds; close lubricator main steam valve. Close air pump main steam valve; leave lubricator condenser valve No. 73 open.

2nd—Open drain valve No. 34 full drain position; close pressure valves No. 62 on both cylinder (low pressure feeds) and open drain valves No. 33 on both cylinder feeds. Next open both feed valves R. & L. No. 175 to vent top of oil bowl.

3rd—When oil bowl is drained, leave cylinder feed valve No. 175 open; leave drain valves No. 33 open. Remove water valve and hub complete from condenser—now close drain valve No. 34 and fill the oil bowl through the condenser. When oil shows up one-half on index glass, stop; as the oil remaining in bottom of condenser will fill up rest of vacant space.

4th—Replace water valve No. 73; close feed valves No. 175; close drain valves No. 33; open pressure valves No. 62 and start lubricator in regular way.

When water valve is broken or disconnected:

1st—Close all feeds; close engine throttle; close lubricator steam valve; close air pump steam valve.

2nd—Open oil bowl drain valve No. 34 and drain all oil and water from bowl. Next remove water valve hub and with screw driver or suitable wire, reach into condenser and push broken part from seat.

3rd—If part is down in passage and cannot be pushed from seat with water valve hub out, open each high pressure feed valve No. 176 and open lubricator steam valve slowly, putting pressure in oil bowl.

4th—After stoppage is removed, apply a new water valve—if none is available, re-apply the old water valve hub—tighten packing around water valve stem, or apply blind gasket and proceed to terminal where final repairs can be made.

To renew glasses: Put washer 70 in first to make a seat between metal and glass; then place gasket on glass, insert large end of glass first; put another follower washer 70 in place on top of gasket and screw packing nut until the necessary resistance is felt.

Regulate feeds to suit requirements.

The draft from an open cab window, if it strikes directly on the sight feed glasses and is permitted to chill the glasses, considerably, may affect the operation of the lubricator; that is, there will be a difference in the rate of feeding when the water is cold over that obtaining when the water is warm in the sight glass chambers. Ordinarily the feeding of the lubricator is affected but very little in this manner, unless a strong current of cold air is allowed to blow on the lubricator continuously.

If there is dirt or other foreign matter in the feed tip 81, or in the choke 57, or if the choke 57 is worn, the feeding of the lubricator may be irregular. A reduced steam pipe, or a steam pipe too small, or an obstruction in the steam or oil delivery pipes will have the same effect. If the chokes are worn or there is a lack of steam pressure on the lubricator, the lubricator will feed faster when the throttle is closed than when open.

With lubricators having solid sight glasses, as described above, no bad results will follow filling the lubricator full of cold oil; because an expansion chamber has been provided to allow the oil to expand when it becomes heated. With the older type lubricators, having tubular glasses, the oil bowl should not be filled to overflowing with cold oil.

If the sight feeds get stopped up blow out the glasses. To blow out the chokes 57, first shut off steam to the lubricator in the pipe connection 9, drain the sight feed chambers by opening valves 33, open the throttle and let steam blow back from the steam chest or valve chambers. If this fails disconnect the pipes and run a wire through the chokes. When necessary to resort to this practice proper report should be made at terminal so that chokes may be put in good order.

When shutting off the lubricator, such as standing in sidings, or other places, close the oil feeds 175 and 176.

The amount of oil fed to the valve chambers should be sufficient to properly lubricate the valves. The amount to be fed depends upon the conditions at all times. No more oil than necessary should be fed, and where oil pipe connections are used in the locomotive cylinders, two drops of oil should be fed to the cylinders for each two fed to the valve chambers. This should be watched particularly when drifting long distances.

To fill the oil bowl close the valve in the steam supply pipe 9 at the fountain, close valve 73 and valves 175 and 176, and 31. Open drain valve 34 and allow all the water in the oil bowl to drain out. As soon as oil shows at drain valve 34 this valve should be closed. Loosen filling plug 23, if the lubricator is hot care must be taken in removing plug 23 as the oil in the bowl may boil out of the opening. After the oil bowl is filled, see that plug 23 is screwed in firmly. In case the lubricator does not operate, the valves may be lubricated through auxiliary oil cups 65.

On locomotives, having oil pipe connections leading into the cylinders, the feeds 175 deliver oil to the cylinders and the feeds 176 deliver oil to the steam chests or valve chambers.

AUXILIARY TO LUBRICATOR

Some locomotives are equipped with an auxiliary to the main lubricator, the auxiliary being located on the boiler head and connected to the main lubricator with suitable pipe connections. Two shut-off valves are located on top of the oil bowl comprising the auxiliary to the lubricator, and which controls a flow of water and oil between these two elements.

To fill the lubricator, close the two valves located in the pipe connections to the auxiliary device and drain and fill the oil bowl in the usual manner.

To drain and fill the auxiliary oil bowl, close the two valves located in the pipe connections thereto and drain and fill in the usual manner.

To use the main lubricator only, turn on steam and open condenser valve.

In order to transfer the oil from the auxiliary device to the main lubricator, open the two valves in the pipe connections at the auxiliary device and leave them open.

INSTRUCTIONS TO ENGINEMEN—MECHANICAL LUBRICATORS

Before departing on a trip either from an originating or an intermediate terminal, the level of oil in Mechanical Lubricator should be noted, and if there is any question as to there being sufficient to take locomotive to next filling terminal, additional oil should be put into the lubricator before departure.

Lubricator should be checked to see if there is any water in the lubricator bowl. If there is, it should be drained off through the pet cock in the end of lubricator base plate. In engine men discover water in the lubricator on the road, drain the water out. Under no circumstances should water be placed in the reservoir of a mechanical lubricator, as may be done with a hydrostatic lubricator. The addition of water will raise the oil level, but will prevent oil being pumped until the water is removed.

The temperature of valve oil in the lubricator bowl should not exceed 125 to 150 degrees Fahrenheit. Excessive heat in the lubricator will not cause the oil to boil, but it may cause any water that is in the bowl to boil, and this will cause the oil to be forced out of the filling opening of the lubricator.

To remedy such a condition: First shut off the steam heat to the lubricator, then drain all water from lubricator bowl. If this does not correct the trouble, it may be caused by leaking check valves, which allow steam to blow back from a valve or cylinder. If this is the case, water will again collect in the lubricator bowl. To prevent the water from raising the oil level to a point where the lubricator cannot pump oil, the drain valve in base plate may be allowed to stand part way open. This will allow water to drain out. Drain valve should be opened wide until all water is out, then closed part way, to allow a continuous drip of oil. Do not let it run a stream of oil. Report condition to next terminal.

Incoming enginemen should know if the valves and cylinders were being properly lubricated. If not, he should call it to the attention of the foreman in charge so that necessary repairs can be made.

If a lack of lubrication is noted on the road between servicing points, at first stop, or special stop if necessary, examine lubricator and piping for visible defects such as broken parts or broken or disconnected oil lines. Also test for water in lubricator.

If broken or disconnected oil line is found and no means are at hand to make repairs, it may be necessary to supply enough oil through the relief valve to protect valve and cylinder on that side, to bring locomotive to next servicing station with as little damage as possible. Notifying the next terminal, giving all information available, will aid in having necessary repairs ready, and will shorten the delay.

If a broken oil line is found and engineman cannot make repairs, bend end of pipe that is connected to valve or cylinder, so as to divert any flow of steam, so that it does not obstruct engineman's vision. That part of pipe connected to lubricator may be tied or wired up, if necessary, until arrival at next servicing point. Under no circumstances should this pipe opening be closed or blanked. If that is done it will result in serious damage to the pumping unit inside of the lubricator, or may cause other broken parts.

When the atmospheric temperature is 40 degrees F. or colder, or when locomotive will encounter this temperature during trip, steam heat must be supplied to lubricator. The steam heat to lubricator must be in operative condition before locomotive leaves terminal. To check the steam heat to lubricator, be sure steam is turned on at fountain, and steam valve at lubricator is open. Open drain valve at the choke fitting, until all water is drained out and steam appears, then close drain valve. In case lubricator cools off from lack of steam heat due to choke being stopped up, the drain valve may be opened sufficiently to allow a light blow of steam to show. This must be reported at next terminal so that repairs may be made. Unless choke fitting is stopped up the drain valve at choke fitting should remain closed at all times while locomotive is in service. Steam heat to oil delivery lines should be on all the time locomotive is in service from October to May.

Some locomotives are equipped with mechanical lubricators on the left side to take care of the lubrication of engine truck journal bearings and hub faces. Some of the later built locomotives are equipped with mechanical lubricators which deliver oil to various parts of the chassis: shoes and wedges, hub faces, engine trucks and trailers.

These lubricators use engine oil, and in general receive the same attention as those delivering oil to valves and cylinders.

It is not necessary to have heat applied to the reservoir of these lubricators as engine oil will flow at much lower temperature than valve oil.

If a broken or disconnected oil delivery pipe from one of these lubricators is discovered, and repairs cannot be made, engineman should apply engine oil from hand oiler and report to next servicing terminal.

INJECTORS

Fig. 58 illustrates the construction of the lifting injector.

List of Parts

1. Body (back part)
2. Body (front part)
3. Delivery end connection
4. Steam valve hub
5. Steam valve nut
6. Steam valve gland
7. Overflow nozzle
8. Lever handle—complete
9. Steam valve crosshead
10. Crosshead lock nut
11. Steam valve stem
12. Swivel nut
13. Steam valve
14. Steam valve washer
15. Primer
16. Steam tube
17. Lifting tube
18. Condensing tube
19. Delivery tube
20. Line check valve
21. Stop ring
22. Overflow hub
23. Overflow valve stem
23A. Handle for overflow valve
24. Overflow valve
25. Overflow packing nut
26. Water valve hub
27. Water valve spindle
28. Water valve packing gland
29. Water valve nut
33. Lever links
37. Coupling nuts
38. Couplings, copper
39. Couplings, iron
152. Closed overflow connection

The method of operation is as follows:

First turn on steam at fountain valve. To start the injector see that valve 23A, and valve 27 are open, then pulling back slightly on handle 8, until the resistance of the priming valve is felt. When water appears at the overflow 7 pull handle 8 back as far as it will go. Regulate for quantity of water desired by opening or closing water or feed valve 27.

To use as a heater close overflow valve 23A, open valve 27 and pull lever 8 back until the resistance of the priming valve is felt. Sometimes the steam pressure inside the injector forces handle 8 clear back, in which event close down on the fountain valve in the main steam pipe, which connects to the injector at 38, until the desired amount of steam is passing through the injector to keep the water in the feed pipe and tank hose warm, and also provide a little circulation of steam through the injector branch pipe. If there is danger of the branch pipe freezing up, the drain cock in the branch pipe located near the boiler check valve should be opened.

The overflow valve 23A must not be closed except when the injector is to be used as a heater. It is important that the tank valve be kept wide open, that all pipe joints and joints at the injector be kept tight, the tank hose strainer should be kept clean, and the packing in the stuffing boxes 6 and 28 should be kept in good condition.

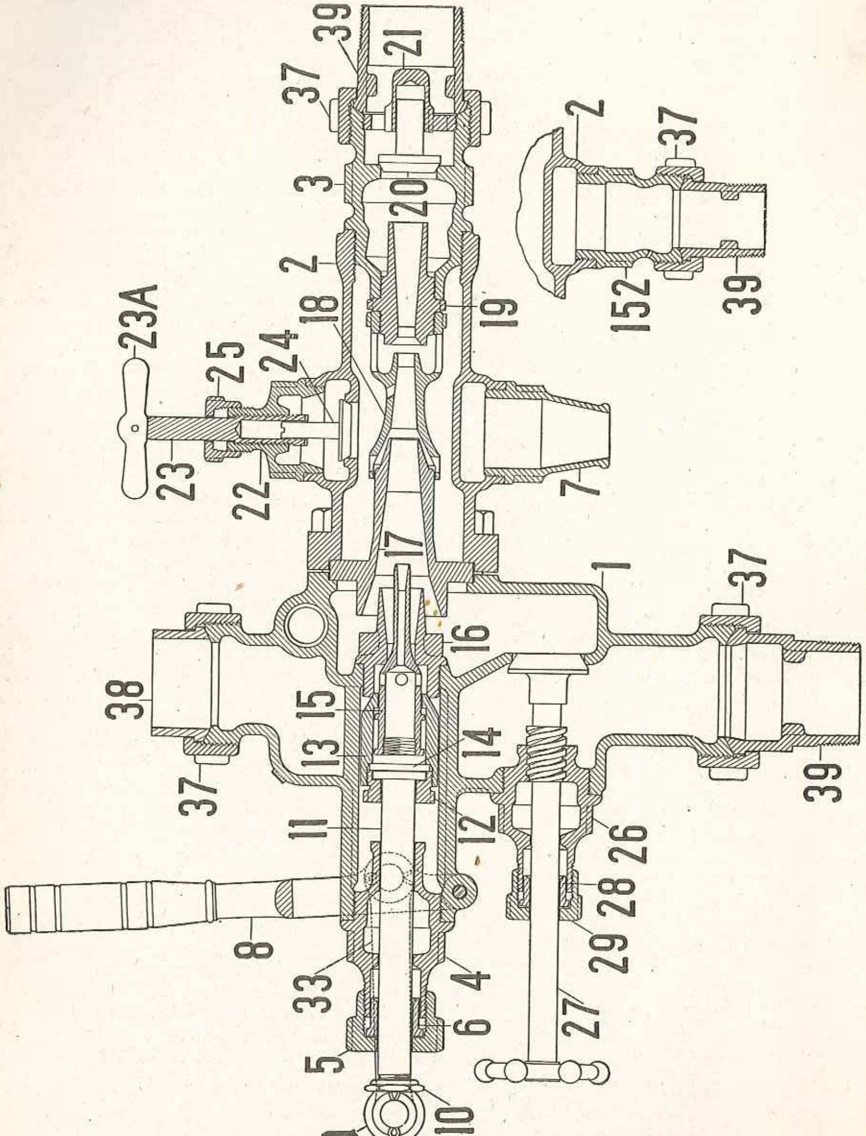


FIG. 58. Lifting Type Injector.

Fig. 59 illustrates the non-lifting injector.

List of Parts

Throttle Valve

61. Body
62. Hub
63. Packing gland
64. Packing nut
65. Valve
66. Swivel nut
67. Spindle
68. Crosshead
69. Lever pin
70. Lever
71. Lever link
72. Link pin
37. Union nut
38. Union nipple
60. Crosshead lock nut

List of Parts

Injector

260. Body
301. Lifting steam jet
302. Forcing steam jet
303. Lifting tube
304. Rear combining tube
305. Forward combining tube
306. Delivery tube
261. Overflow body
262. Overflow connection nipple
263. Overflow connection nut
264. Overflow cap
265. Overflow hub
266. Overflow stem
309. Overflow check
312. Overflow packing nut
313. Overflow packing gland
307. Barrel cap
267. Water valve hub
268. Water valve stem
269. Water packing gland
270. Water packing nut
316. Water valve disc
317. Water valve swivel nut
328. Water valve wheel
329. Overflow valve wheel
337. Steam union (nut and nipple)
338. Supply union (nut and nipple)
339. Delivery union (nut and nipple)
271. Universal joint

To operate the non-lifting injector, first turn on steam at fountain valve, see that the water valve 328 and the overflow valve 329 are open. Pull back gradually on handle 70 of the steam throttle valve until wide open. If the injector is working properly there should be no water spilling at the overflow 338.

The desired supply of water to the boiler may be regulated by either opening or closing water feed valve 328. When the injector is shut off close the water valve 328 and leave the overflow valve 329 open.

To use as a heater, close overflow valve 329 and open water valve 328, shut off fountain valve in main steam pipe which connects to injector at 337; then move handle 70 back to open steam valve 67 wide, then open the fountain valve sufficiently to obtain the desired amount of steam to keep the water warm in the injector, feed pipe and tank hose, also to provide a little circulation of steam through the branch pipe. The drain cock in the branch pipe, near the boiler check should also be open.

The principle of operation of the injector is as follows: Its power to force water into a boiler against its own steam pressure is due to the difference between kinetic or moving energy, and static or standing energy. Steam at the ordinary boiler pressure travels at a very high velocity and when placed in contact with a stream of water it is condensed into water, at the same time imparting its velocity to the water which condenses it. This, of course, gives a high momentum to the body of water with which the steam comes into contact. The momentum imparted to the water in an injector is enabled to overcome a pressure greater than the original pressure of the steam.

The velocity of the steam passing through the tubes in an injector is imparted to the water entering the branch pipe, which gives the water in the branch pipe sufficient energy to open the check valve and enter the boiler against its own pressure.

Injectors of the lifting type must, of course, create a sufficient vacuum in the water feed pipe to raise the water from the level in the tank to the height of the injector. In other words, the priming valve drives the air out of the injector, which causes a vacuum in the feed pipe. This allows the atmospheric pressure on the water in the tender to force the water through the feed pipe into the injector, where it condenses the water passing from the priming valve and flows out through the overflow pipe.

Injectors of the non-lifting type are located below the level of the water in the tank so that the water will flow to it by gravity. If there is a bad leak which admits air into the water feed pipe the lifting injector will not work, it will not prime because the leak destroys the vacuum necessary to raise the water in the feed pipe. However, a non-lifting injector may work under these conditions, particularly if the water escaping from the pipe prevents any air being drawn into it as is the case with the lifting injector.

Other causes for the injector not working are an insufficient supply of water or the tank valve being closed or partly closed. The strainers may be stopped up or the tank hose kinked. Injector tubes out of line or badly limed up, the delivery tubes may be cut out, there may be too much water in the steam coming from the boiler, or the water in the tender may be too hot. Trouble may be experienced in getting the injector to prime properly if there is an insufficient water supply in the tank, or if the tank valve is closed or partly closed. There may be an obstruction in the tank hose or strainer may be stopped up. With the lifting type injectors, the trouble may be caused by a leak in the water feed pipe. Also if the boiler checks are leaking badly or stuck up, or the injector throttle leaks bad. The boiler check may be stuck shut or there may be an obstruction in the branch pipe. The line check valve may be stuck shut or broken.

If, when the injector is shut off or not working, steam or water shows at the overflow pipe, this may be either from boiler check leaking or the injector throttle leaking. Closing the main

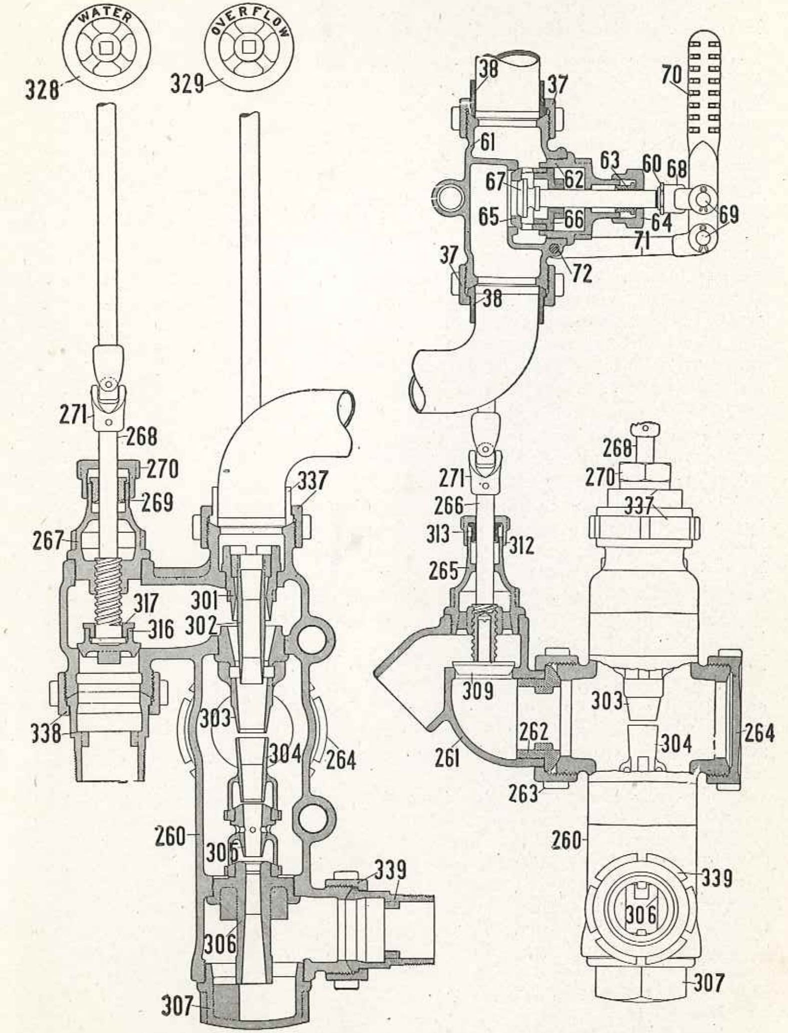


FIG. 59. Non-Lifting Type Injector.

steam valve on the boiler will stop the flow of steam or water, if it comes from the injector throttle. In case the primer valve is leaking, it will not prevent the primer or injector working, but may waste considerable water from the overflow.

Sometimes all the steam passing through the injector is not condensed by the water. Under these conditions the injector may work but spill hot steam and water at the overflow. If only a very little steam is condensed, the injector will not work. If the injector spills cold water at the overflow, there is too much water for the amount of steam passing through the injector. If some steam and very hot water escapes at the overflow while the injector is working, there is too much steam for the amount of water being supplied. In the former case the amount of water passing through the water feed pipe should be reduced and in the latter case the amount of water passing through the water feed pipe should be increased, or the steam pressure reduced. It may be that in the former case there is not sufficient steam pressure on the boiler, or the steam fountain valve not opened wide enough, and in the latter case an obstruction somewhere in the water supply leading to the injector.

A leaky injector throttle heats the water in the top of injector water pipe. If this hot water can be blown back into the tank the injector will prime.

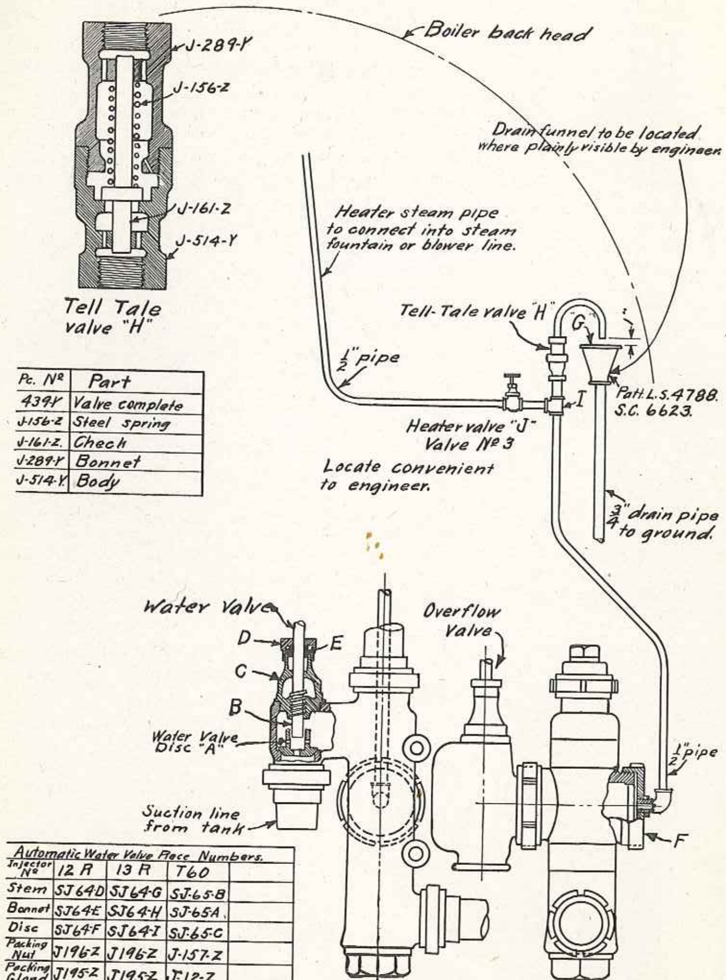
If the injector primes properly, but breaks when steam is turned on wide, examine main steam fountain valve and valve on injector steam pipe, to see if full open. Next examine feed line for obstructions. If injector continues to fail, examine combining and delivery tubes for defects or obstructions.

If the injector will not prime examine from overflow back, including the steam supply pipe connections, strainers, hose, hose couplings, tank valve or syphon pipe.

In case the boiler check valve is stuck open, tap the check case lightly on the top or bottom. If using a hammer or other metal piece, do not strike the check valve cage heavily on its side, as this tends to spring the check case so that the check valve will not seat tightly.

It is sometimes possible to get the injector to prime and start working by opening the drain cock in the branch pipe, if the branch pipe or check is equipped with a connection for filling the boiler, this may be opened to reduce the pressure at the injector to assist in getting the injector to prime. If the water is not forced into the boiler, gradually close the water feed until the injector does start the water through the check valve into the boiler. The water feed valve may then be adjusted to the desired position. After getting the injector to work, all openings made in the branch pipe should be closed. If it is impossible to get the check valve seated, or the injector to work, close the water feed valve and the overflow valve, then close the injector steam pipe fountain valve to separate the injector from other connections at the fountain.

To operate the injector as a heater, close the overflow valve, open the drain cock in the front end of the branch pipe and close the valve in the injector steam pipe at the fountain. Open the injector throttle, then slightly open the fountain valve to the injector to admit sufficient steam to provide for circulation through the branch pipe and the tank hose to prevent freezing. At the same time care should be exercised not to admit sufficient steam so that too much pressure will be built up which might cause the tank hose to burst or blow off. Do this in freezing weather on injectors which are not being operated regularly, to prevent freezing up of the branch pipe, feed water pipe and tank hose.



Pc. №	Part
439-Y	Valve complete
J-156-Z	Steel spring
J-161-Z.	Check
J-289-Y	Bonnet
J-514-Y.	Body

Automatic Water Valve Piece Numbers.

Injector №	12 R	13 R	T60	
Stem	SJ64-D	SJ64-G	SJ-65-B	
Bonnet	SJ64-E	SJ64-H	SJ-65-A.	
Disc	SJ64-F	SJ64-I	SJ-65-C	
Packing Nut	J196-Z	J196-Z	J-157-Z	
Packing Gland	J195-Z	J195-Z	J-12-Z	

FIG. 60. Piping Arrangement Non-Lifting Injector Tell-Tale.

NON-LIFTING INJECTOR — CLOSED OVERFLOW OPERATION FOR LOCOMOTIVES EQUIPPED WITH FEED WATER HEATERS

Injectors on all locomotives with feed water heaters are equipped for closed overflow operation as described below.

Remove present water valve disc "A," stem "B," bonnet "C," packing nut "D" and packing gland "E" and apply automatic water valve parts according to table on Fig. 60.

Drill and tap cap "F" apply ½" street ell and pipe as shown.

Drain funnel "G" to be located where plainly visible by engineer.

Telltale valve "H" to be located in pipe between drain funnel "G" and heater line tee "I."

Heater valve "J" and piping to be applied as shown. Heater pipe to terminate in blower line above auxiliary throttle valve or in steam fountain.

TO OPERATE INJECTOR

Open water valve, overflow valve and steam valve in the usual manner. When the injector starts to deliver water to boiler the overflow valve should be closed. As long as injector delivers water to boiler there will be no steam discharge into drain funnel, however, should injector "break," steam will be discharged at this point. Injector steam throttle should then be closed immediately and injector started again.

TO OPERATE INJECTOR HEATER

When injector is not in operation and feed line is in danger of freezing proceed as follows:

Open water valve.
Close overflow valve.
Open heater valve "J."
Open branch pipe drain cock at boiler check.

If steam is discharged into drain funnel, valve "J" is opened too wide and should be throttled down until the discharge stops.

To test telltale valve "H" with overflow and water valve closed, open injector throttle to priming position. If telltale valve is O. K. steam will discharge at drip "G."

If water is below 100° temperature injector should be operated in the usual manner.

If water is over 100° temperature, start injector in the usual manner and if water spills at overflow open water valve wide, then close overflow valve, after which the water valve may be adjusted for the desired feed to boiler.

When injector is shut off, water valve should be closed and overflow valve opened.

FIRE JETS

The fire jet on switch locomotives is a device operating on the principal of the injector. There are four openings into the device. The top one is connected to the steam supply on the locomotive. The two horizontal openings are for water supply, one of which is connected to the locomotive tank, the other may be used for an auxiliary water supply, as from a fire hydrant, in case the tank supply is exhausted. Water must flow to the jet in all cases, as it will not form a suction and lift water. The fourth opening is the delivery hose connection and is on the bottom, in line with the steam flow into the device.

The hose is carried on a reel on the top or back portion of the tank.

OPERATION

Remove the hose from the reel. Remove cap from bottom opening, and connect hose.

Turn on water supply, and then turn on steam gradually, to full pressure.

To shut off, first turn off steam, then turn off water supply.

ELECTRIC HEADLIGHT

The electric headlight equipment on a locomotive consists of a turbine motor connected to a dynamo, the dynamo and motor being constructed as a single unit and both being rigidly attached to a single shaft, the turbine motor being operated by steam taken from the boiler.

Fig. 61 shows the type "E" motor and dynamo complete, and Fig. 62 the type "E-3." Type "E-2" is not shown but is similar to type "E" except it is smaller.

Fig. 63 shows type of adjustable lamp stand which sets directly behind the reflector and to which the reflector is attached.

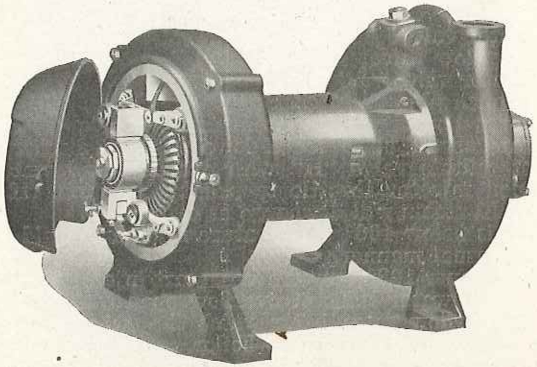


FIG. 61. Type "E" Headlight Turbine and Dynamo.

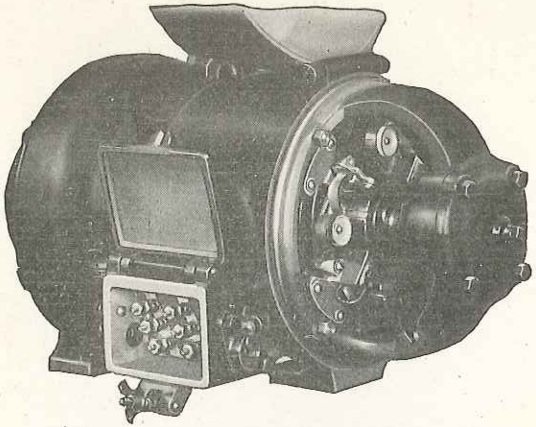


FIG. 62. Type "E-3" Headlight Turbine and Dynamo.

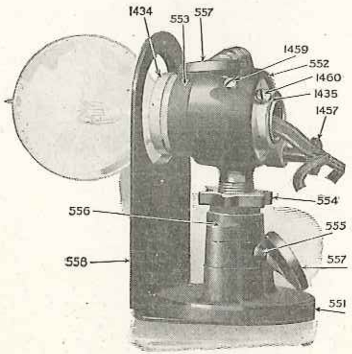


FIG. 63. Adjustable Headlight Lamp.

A system of wires connects the dynamo to the headlight and the cab lamps. A switch, conveniently located in the right side of cab, provides for turning on and off the headlight as desired.

The headlight should be adjusted so that the front edge of the reflector will be parallel with the front edge of the headlight cage or case. To focus the lamp, the locomotive should be on straight track and adjustment shall be made to obtain a parallel beam of light straight down the center of the track. All of the adjusting screws should then be tightened firmly. For road work the shaft or beam of light should extend at least 800 feet ahead of the locomotive, and for yard work at least 300 feet. Cage should be set square and level and be bolted down tight before adjustments are made.

A newly applied headlight should always be focused before going into service. This can best be done at night or in a dark room. To focus the light, throw the light from the reflector upon a wall or the end of a car from fifty to seventy-five feet away, and manipulate the lamp (up and down or side-ways) by using the focal adjusting thumb screws of the focusing device until a perfect light circle is obtained. The light is in focus when the light circle is reduced to its smallest possible size by movement of the lamp forward or backward. After obtaining a good focus tighten the lock nuts on the focal adjusting screws, place the reflector in its case and close the door. The light beam should be central on straight level track and should be directed so as to define persons from 800 to 1,000 feet way. If the beam of light is not central it may be necessary to swing the headlight case to the right or left on its bracket. To raise or lower the beam of light it may be necessary to shim up the front or back of the headlight case as required. A black spot or shadow on the track within the light rays indicates that the lamp is not in focus in its reflector.

When renewing globes in the headlight it may be necessary to re-focus the lamp, as the filament or wire in each globe is not located the same in exact relation to the center of the globe.

To insure a good and unfailing light a careful inspection should be made of the lighting equipment before departing on each trip. All screws and connections should be known to be tight and also that there is oil in both bearings, and that steam does not blow at the stuffing box gland.

During winter months dynamo oil should be used for lubricating and during the summer months a mixture of half and half dynamo oil and valve oil should be used. Do not use valve oil alone, such oil is too heavy to be carried up to the shaft by the oil ring, particularly in cold weather. The turbine bearing should be oiled each trip. Oil for the dynamo bearing is introduced through an oil cup located on the side of the main casing at the back of the dynamo. When a hinged oil cup cover is used do not fill the cup completely full. When a screwed oil cup cover is used the cup may be completely filled. To oil the turbine bearing of the E and E-2 machines, an oil cup is located on the turbine cover. On the E-3 and MO-6 machines, the oil cup is located on the side, and for dynamo end, under the dynamo door.

In starting the motor and dynamo turn the steam on slowly at the fountain valve in the cab, in order to permit the water from condensation to pass through the drain pipe. The throttle valve should be opened wide when in regular service, so that the lights will burn clear and bright. The speed of the turbine motor is controlled by the governor.

The most vital part of the dynamo, which is, of course, that part of the equipment which generates the electric current, is

the commutator. The commutator must be kept clean and free from dirt. The mica strips between the sections of the commutator must be kept below the surface of the commutator face. In cleaning the commutator remove all brushes and rub lengthwise of the bars with a piece of moist clean waste. This removes the carbon dust from between the segments or bars as well as all dirt from the surface of the commutator. Replace brushes, and generator is ready to start.

If it is necessary to clean the commutator by polishing it, it should be smoothed by means of a strip of No. 0 sandpaper held in contact with the commutator while turbine is running. Hold sandpaper by its ends and do not press against it with the fingers, as this will increase the size of any spots that may be on the commutator. The mica insulation between the commutator bars should be maintained 1-64 inch below the surface.

The brushes which bear on the commutator should have a bearing of the same contour as the commutator. The brushes may be fitted by cutting a strip of No. 0 sandpaper the width of the commutator surface, then press the strips of sandpaper under the brushes, with the back of the sandpaper next to the commutator surface. Allow the brushes to drop in place, then pull the sandpaper from left to right until the brushes have been fitted to a true smooth bearing, then trim about ⅛ inch off of the front end of the brushes. Never attempt to fit a brush with a file.

When trouble suddenly occurs, if the light has been burning steadily and nicely and then suddenly begins to flash badly, the trouble will usually be found at one of the binding posts, on account of the binding post screws becoming loose. If the light is burning satisfactorily and suddenly goes out it may be that either a fuse has burned out, the lamp has burned out, one of the lead wires has broken between the dynamo and lamp or one of the wires has become loose at its binding post and fallen out. If the light goes out between stations and an investigation cannot be made within a few minutes thereafter to determine the cause, steam should be shut off from the turbine motor until such time as the cause of failure can be determined. Otherwise if the failure is due to a short circuit damage might be done to the coils or armature in the dynamo by overheating.

When there is a short circuit in any of the connections, which is brought about by the insulation on the wires becoming worn off until two wires can come together either directly or through the medium of some metallic substance, the turbine motor will labor heavily and run slow with a great volume of steam blowing at the exhaust. There will be no light shown at the headlight or cab lamps, or the cab lamps may only show a dull red light.

In the case of a short circuit due to the insulation being worn off the wire or the wire touching some metallic substance, if the exposed wire can be located, wrap it with a piece of waste or cloth to act as insulation.

In case of a broken wire if the broken section can be gotten at, temporary repairs might be made by stripping off the insulation for enough back at the end of each section so that the two pieces of wire might be firmly bound together. See that the ends of the wire are scraped thoroughly clean before twisting them together, wrap the joint in the wire with a piece of cloth if there is liability of them touching anything.

Sparking of the commutator at the contact of the brushes may be caused by the brush being poorly surfaced, the brush may be too short, the commutator surface may be rough or the commutator may not be running true, the mica between the commutator bars may need dressing down.

If the governor valves should become stuck shut or the governor springs are too weak, the light may go out or burn dim in which case the action of the turbine motor should be reported on arrival at terminal.

If the cab lights burn up bright when the headlight is cut out, throttle the steam to the turbine motor and report same on arrival at terminal.

The commutator brushes stick up at times in which case the dynamo will not generate current. Poor contacts at switch points and also commutator brushes will keep the light from burning.

The speed of the dynamo is regulated by the governor so that the voltage will not be over 32 volts at any time. Any voltage over 32 shortens the lamp hours and burns out lamps more quickly. Governor valves stick open or shut at times when strainers are stopped up. A little engine oil applied at times through the steam pipe will avoid most of this trouble.

The wiring system for road locomotives is made up in two sections, one section comprising the lighting system for the headlight and dimmer, the other section comprising the balance of the light on the locomotive. A double throw switch is for the purpose of operating the headlight and dimmer. The cab lamps are operated constantly. The classification lamps are operated by a single throw switch on the left side of the cab. A separate fuse is used for each lighting section. On road locomotives having a headlight at the rear an additional section is applied, controlled by a double throw switch.

On new locomotives and locomotives having revised wiring, a single switch with four positions controlling front and rear headlights and dimmers is used. Additional switches are provided to control all other lights on locomotive except water glass lamps.

In case an individual lamp fails to burn and all other lights burn properly, examine to see if the light has burned out and needs renewing. If none of the lights on a particular section will burn, examine to see if the fuse in that section has burned out. If a fuse has burned out and a new fuse is applied which burns out when the current is turned out, it is evident that some defect exists in the wiring system which causes the fuse to be burned or blown out. To determine if the defect is in the wiring system, or either one of the lights, remove the lights

from their sockets in that section, turn on the current and see if the fuse holds, if so, start applying the lights in their sockets until the one is found which causes the fuse to burn out, and either replace or leave the light out of its socket. Sometimes the light becomes loose in its socket so that it does not make a proper contact, in which case screwing the light firmly in place overcomes the trouble.

The headlight or other lights about the locomotive which are operated by the turbine generator should not be used unnecessarily, and should not be burned during the day time unless absolutely necessary. It requires forty to fifty pounds of water per hour to operate the turbine when only the cab lights are burning, therefore unnecessary use of the light is simply a waste of fuel and water. The turbine motor should be shut off when it is not necessary to use lights.

In case it becomes necessary to substitute for a fuse, report should be made on arrival at terminal. In case locomotive is turned over to another crew, as in case of locomotives on through runs or switch locomotives working on more than one shift, the fact that the fuse has been substituted for, should be reported to the relieving engineman or notation made on work report.

The Keystone dynamo is also used on some road locomotives. The preceding instructions will also apply to the Keystone dynamo.

THE CLOSED TYPE FEED WATER HEATER

The feed water heater consists of a steam driven water pump, heater, gauge and a condensate trap. The pump replaces the injector on left side of locomotive and the water which is forced into the boiler by it, instead of going directly to boiler check as is the case when the injector is used, passes first through the heater.

In the heater the water passes through small tubes. These tubes are enclosed in the chamber of the heater, into which the exhaust from the air compressor and feed water pump is piped and through which also a portion of the exhaust steam from the locomotive cylinders passes. The water, in passing through the small tubes absorbs heat from the exhaust steam, which would otherwise be wasted at the stack and the heat so obtained reduces the amount necessary to be provided from the firebox after it enters the boiler.

The purpose in adopting the heater and pump principle, is to reclaim as much of the heat in the exhaust steam as is possible. The best and most successful means for getting it back in the boiler is to transfer it to the boiler feed water. In turn this accomplishes two things. First, waste heat is reclaimed. Second, the feed water is preheated.

This waste heat is reclaimed when a part of the exhaust steam from the engine cylinders and auxiliaries is passed to the heater (a condenser) where it comes in contact with the small copper tubes through which the water at a lower temperature is passing and absorbs the heat in the exhaust steam. In addition to acting as a medium for carrying this waste heat back into the boiler, the water is also heated. That is why the apparatus described herein is called a feed water heater rather than a heat exchanger.

After the exhaust steam has given up its heat to the feed water in the tubes, it condenses and is again in a state of water, termed condensate. It is then returned by gravity to the tank for use as feed water.

A pump instead of an injector is used with a feed water heater permitting the water to enter the heater at temperatures as low as possible thereby absorbing the largest amount of heat possible from the exhaust steam. Water leaving an injector, has been heated by the live steam, used to operate it, and, very little, if any, heat from the exhaust steam could be absorbed.

The heater is a steam tight drum, enclosing a nest of copper tubes through which passes the water to be heated.

Steam for driving the pumps is taken from the main turret. A valve in the steam line to the pumps, is marked "Water Pump." This is located conveniently to the fireman. The turning of this valve controls the speed of the pump, therefore the amount of water fed to the boiler. The exhaust steam from the pump goes into the feed water heater.

Lubrication of the pumps is effected either from the main engine lubricator or by a separate single feed lubricator.

A special pressure gauge is placed in the cab and is connected to the discharge of the pump. The swing of the gauge hand indicates the pump speed. This swing should not exceed a range of 50 lbs.

The CF type pump, Figs. 64 and 65, is a two cylinder double acting pump with 8-in. steam cylinders, 5½-in. water cylinders and 9-in. stroke. Each steam cylinder is fed from a common line. The right hand cylinder, No. 1, is self-controlled; the operation being exactly the same as that of the W-6½ type pump and Westinghouse 9½-in. air pumps.

No. 2 pump is dependent for reversal on No. 1 pump. Valve pistons C and F, Fig. 65, are of equal area and are connected with No. 1 steam cylinder wall with control pipes LB and GJ.

As main piston A passes port B on its upward stroke, live steam is admitted through control pipe BL to chamber P at left of piston C. As port J is still open to exhaust, pistons C and F move to the right carrying main valve D with them. Live steam enters port E and drives main piston H upward.

As piston A passes port J, the pressures in chambers P and Q are equalized, resulting in no motion of valve D.

When piston A reverses itself at the upper end of its stroke, the steam below it is exhausted. At the same time the pressures in chambers P and Q are also dropped to exhaust pressure but remain equalized, resulting in no motion of main valve D.

As piston A passes port J on its down stroke, live steam is passed through control pipe JG into chamber Q, forcing pistons C and F, together with valve D, to the left, reversing piston H.

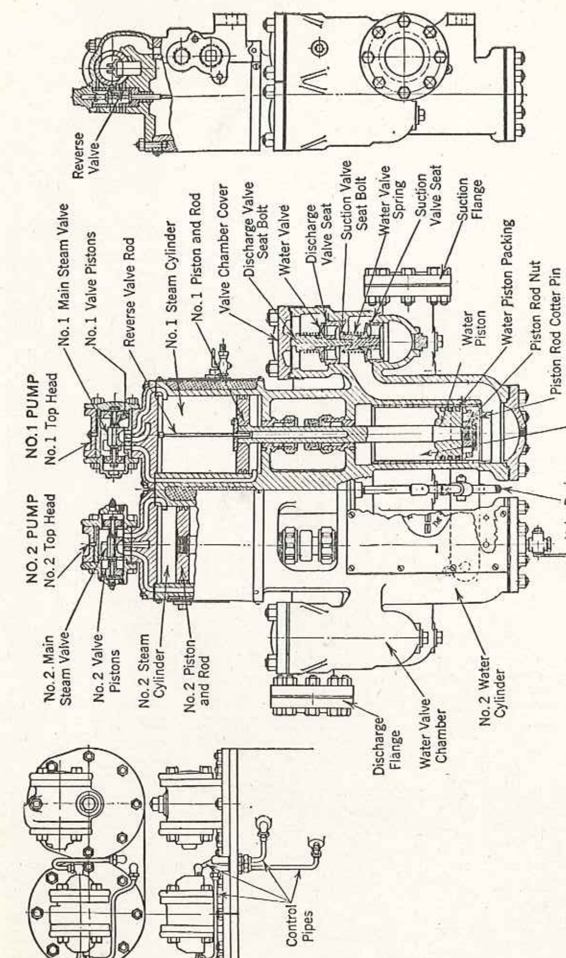


Fig. 64. C F-Type—Boiler-Feed Pump.

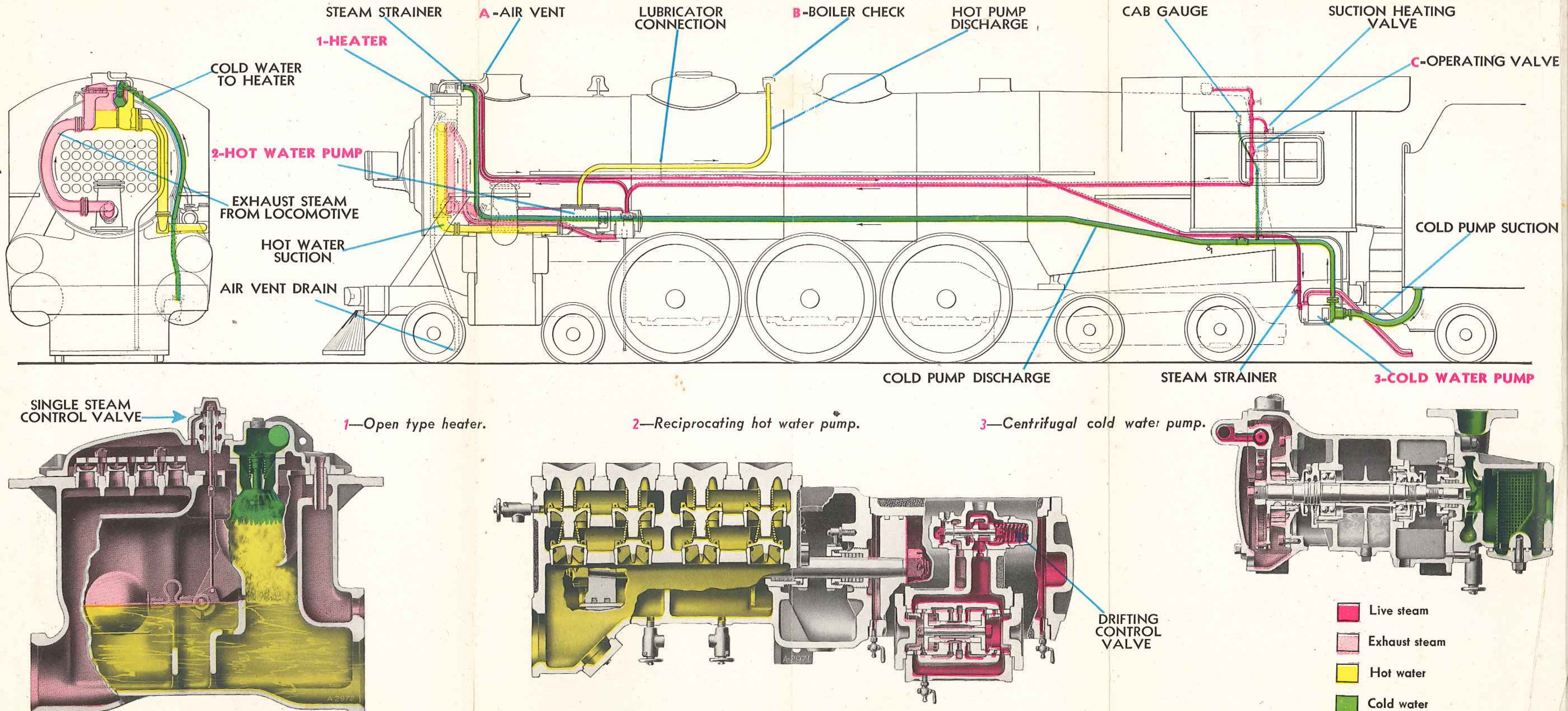


Fig. 70—Open Type Feedwater Heater

G-142 425 VB

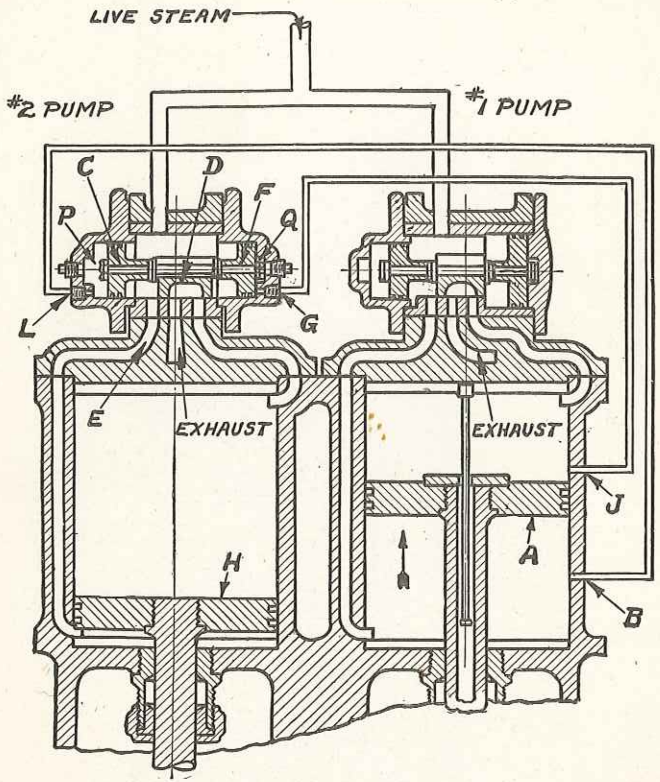


FIG. 65. C F Type Boiler Feed Pump Operating Diagram.

When starting the pumps cold, No. 2 pump may not start at once due to condensation in the control pipes and No. 2 top head. After No. 1 has made a few strokes, these parts warm up and No. 2 goes to work. **For this reason it is advisable to crack the pump throttle until the pump has warmed up.**

This pump produces a continuous flow of water in the discharge line, which holds the boiler check off its seat and eliminates check pounds. The water end has no discharge air chamber but has a suction air chamber, incorporated in the casting between and behind the cylinders and yokes.

The water ends of this pump are lined with bronze bushings and on each side there are the valve chambers connected by passages. Each valve chamber contains a set of two suction valves and set of two discharge valves; each set being arranged in deck form for easy removal.

The CF type pump has a maximum capacity of 9,600 gal. or 80,000 lbs. water per hour.

ELESCO W-6½ TYPE PUMP

The general arrangement of the W-6½ type pump is shown in Fig. 66. In Fig. 66, the water cylinder and one valve chamber is cut away to show the interior parts. This pump is single cylinder double acting; the steam end is essentially the same as that of the Westinghouse 9½-in. air pump. The diameter of the steam cylinder is 9½ in., that of the water cylinder 6½ in. and the stroke 10 in.

The water end of the pump is lined with a bronze bushing and on each side are the valve chambers connected to it by passages. It includes the water cylinder, two valve chambers (one for each end of the cylinder), suction and discharge air chambers. Each valve chamber contains a set of five suction valves and a set of five discharge valves, each set being arranged in a removable deck. All valves are alike. There are passages back of the cylinder which connect the spaces below the lower decks, and above the top decks of the two valve chambers. The spaces between the decks connect with the water cylinder, the one on the right to the bottom and the other to the top.

Two air chambers are used, the one on the right being the discharge air chamber, and that on the left the suction air chamber. These are applied to cushion the water hammer.

HEATER

A closed type feed water heater is used, Fig. 67. In this type the exhaust steam surrounds copper tubes and heats the water passing through them. Thus the exhaust steam and feed water are separated.

For a large locomotive, a heater has about 156 copper tubes, ⅝ in., outside diameter, and $\frac{1}{16}$ in. thick (No. 16, B. w. g.) which are secured into thick tube plates at either end by a special grooved and tapered joint. One tube plate is secured to the end of the heater body, but the other is free to move length-

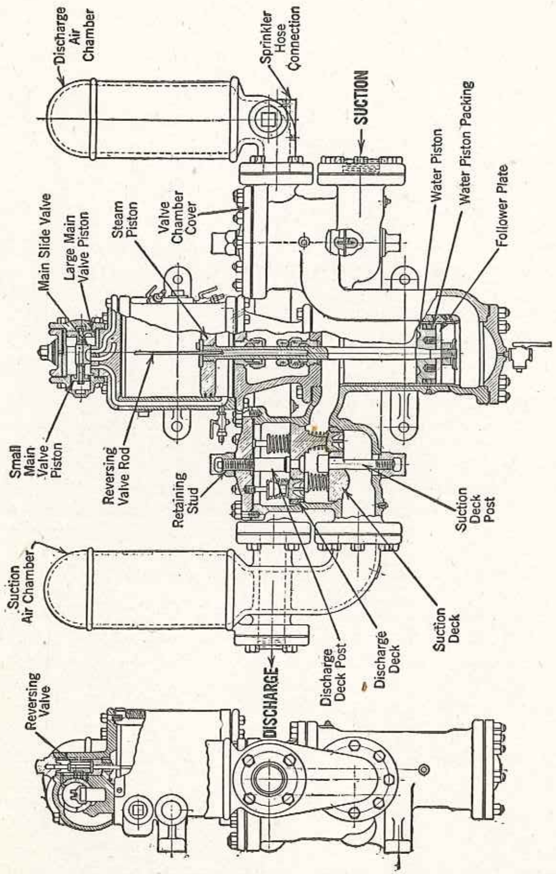


FIG. 66. W-6-½ Type Boiler Feed Pump

wise and allow free expansion of the heater tubes. By dividing the tubes into four groups and providing quarter and half headers, the water has to pass through one group or quarter and then back through the next, and then into the third and finally through the fourth group. The tube plates are more than 4 ft. 6 in. apart, so by this arrangement the water has to travel over 18 ft. in the hot tubes and becomes heated nearly to the temperature of the exhaust steam.

Exhaust steam from the locomotive cylinders is brought into the heater body at the top. This steam fills the heater around the tubes and as it gives up its heat, it condenses and drains away through the bottom of the heater. This is called the condensate.

The exhaust steam entering the heater comes in contact with the tubes filled with cold water and gives up its heat to the colder body. In doing so, the steam is rapidly condensed, leaving a partial vacuum in the heater which effects a reduction in back pressure on the main engine pistons.

When the heater is in the pilot location, as shown on Fig. 68, an air-operated, water-elevating device, a condensate return tank, Fig. 69 is installed in some convenient place below the level of the heater.

Fig. 69 shows the construction of this trap. A float and arm of essentially the same construction as used in the return tank

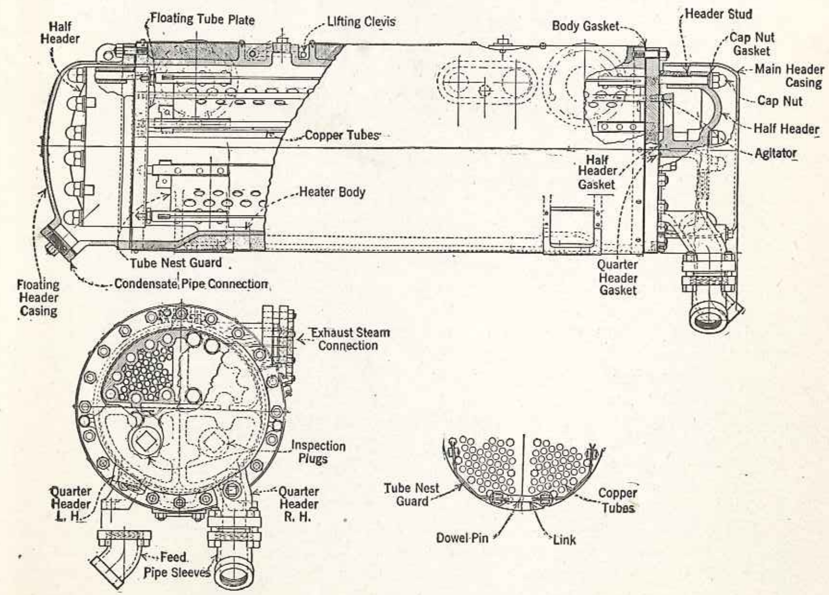


FIG. 67. Closed Type Feed Water Heater.

is employed. This is enclosed in a cast iron tank to which is connected the condensate pipe from the heater. The float operates a shaft with a short arm which connects through a link to a balanced valve in the outlet from the tank.

When water is being discharged through the line the float is raised and the valve is open and the condition is the same as if the trap were not installed. When steam is discharged from the heater the float drops and closes the valves.

Failure of the trap could leave the valve closed, which would fill the heater with condensate. This would be evidenced by water at the stack. An emergency valve stem is placed in the trap to cut the trap out of service in case of failure. In normal operation it should be screwed out to its limit. Screwing-in this stem opens the trap discharge valve and keeps it open, permitting the passage of water and steam into the tank.

The water going to the pump, on locomotives equipped with this trap, will generally be 15 to 20 degrees hotter than the water in the tender.

The trap should be drained in freezing weather, or should be protected by a separate steam heat line.

The trap may be opened for inspection without breaking any pipe connections or disturbing any of the moving parts. See Fig. 69.

Before leaving the terminal be sure the tank valve and the boiler check valve are wide open. Crack the steam valve on the pump line, and after the condensate in the steam pipe to the pump has had a chance to work out, note that the water pump gauge needle has a regular swing which shows that the pump is operating properly. If this swing exceeds 50 lbs., regulate it by partially closing the valve in the gauge line.

Set the lubricator to feed about 1 drop of oil a minute for the W-6-½ type pump and from 2 to 4 drops for the CF type pump. Use the pump as water is needed, setting it to feed a steady stream and hold a constant level. Usually a half turn or less of the pump steam valve will be sufficient.

If pump does not start readily make sure steam valve at the turret and the emergency valve at the pump are open. Open the sprinkler hose valve and run pump until solid stream of water is discharged. If pump does not start with sprinkler hose valve open, there may be a stuck reversing valve that can be loosened by tapping the top cap with a hammer.

If the pump does not supply enough water it may be due to a clogged strainer, a partially closed tank valve, a loose lining in the tank hose, chunks of coal closing the openings in the tank valve or loose water piston packing, loose pump valve, or valve decks. In a great majority of cases the trouble will be found in a clogged hose strainer or a partially closed tank valve.

If there is a leak causing a loss of water after it has left the pump, it will be evident by the pump running noticeably faster.

If the pump runs with an uneven stroke which will be shown by an unequal swing of the hand on the cab gauge, and does not

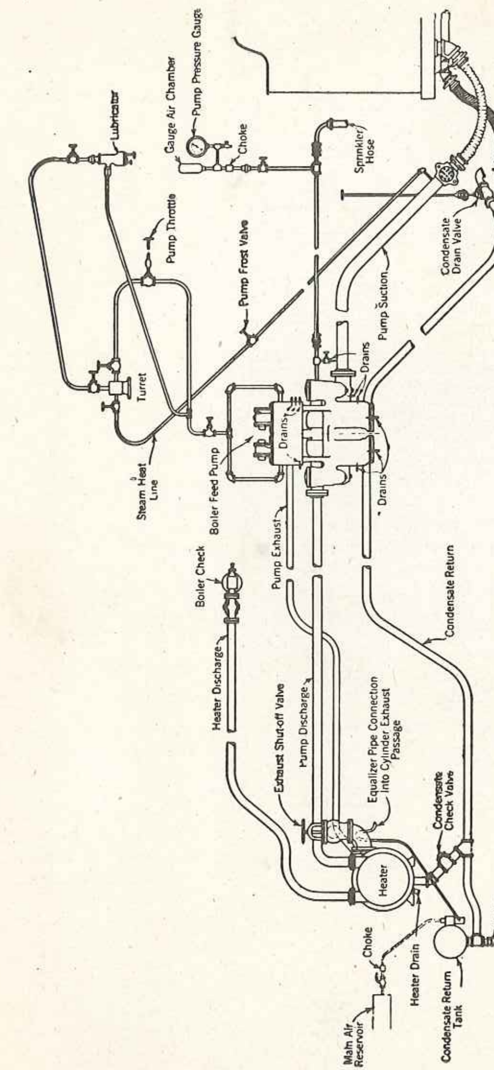


FIG. 68. Diagrammatic Outline of Closed Type Heater in Pilot or Lower Location Showing the Heater, Pump, Condensate Return Tank, Piping Connections

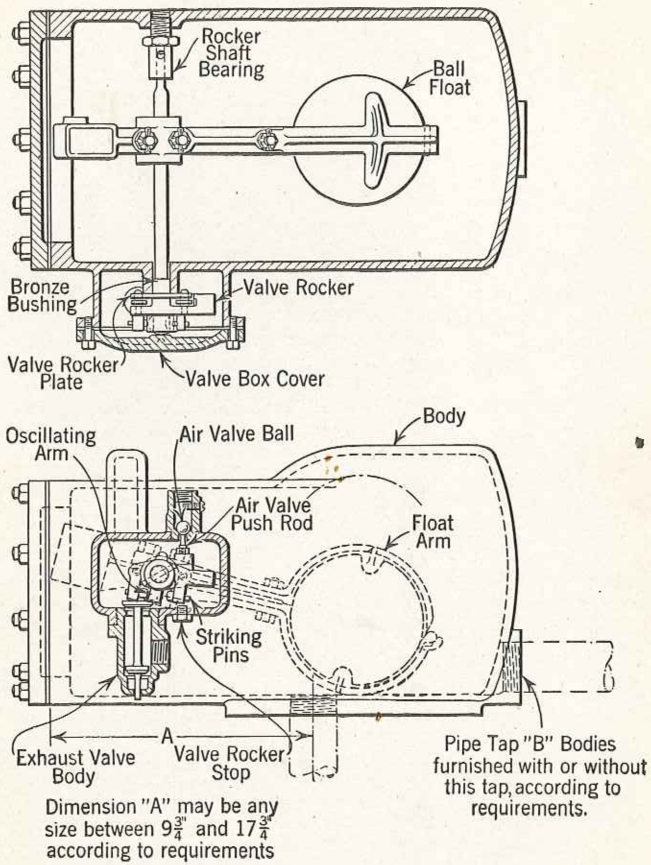


FIG. 69. Condensate Return Tank

supply enough water, the trouble is due to a stuck or broken valve in the pump, or to air in the lower end of the water cylinder. Opening the sprinkler hose valve will correct the trouble if caused by air.

In case the W-6-½ pump hammers or pounds the cause is either air entering the suction line, or a loss of air in the discharge air chamber, or clogged strainer.

If air is being drawn into the suction line, it can be detected generally by a water leak.

If the discharge air chamber is filled with water it can be cleared by closing the tank valve, and opening drains on water end of pump. Run the pump slowly for a few minutes until all water is discharged. Then stop the pump, close the drains and open the tank valve, start the pump again and leave the squirt hose open until solid water is discharged.

If it is thought that the packing of the water piston is worn and is letting water by, it can be tested by closing the boiler check valve and cracking the steam valve to the pump. Watch the rod and if the piston does not move at over six double strokes a minute, the packing is in satisfactory condition. **Do not allow the pressure as shown on the cab gauge to be over 300 pounds.**

Whenever the pump has to run at a considerably higher speed than has been usual in order to supply the boiler but operates at an even stroke as shown on the cab gauge and if the piston packing is tight, the reason is generally a leak somewhere between the pump and boiler check.

If the condensate line becomes plugged by a kinked hose or in any other manner, the engineer will discover the trouble by water coming out of the stack with the exhaust. Since this water reaches the exhaust passage outside the cylinder port, it is not possible for any of it to enter the cylinders while the locomotive is working steam.

When this occurs, stop the pump and use injector for balance of trip. At the terminal, report condensate pipe plugged.

There are other causes for priming or water coming out of the stack with the exhaust and when this does occur, the engineer should close off the water pump for a few minutes, and see if the priming stops, before deciding that the heater equipment is to blame.

When leaving locomotive on ash pit shut off pump. Close lubricator. In freezing weather, open condensate drain valve on locomotives where condensate is piped to tender. **If the locomotive is equipped with a condensate trap leave this drain valve closed to avoid drawing water from tender.**

In very cold weather the heater valve in the pump suction steam heating line should be opened slightly. When standing on a side-track for some time the pump can be allowed to run very slowly and avoid all danger of freezing.

When leaving the locomotive where it may be without attention for some time, the safe procedure is to open the heater valve a half turn and close down the pump, then open the squirt hose valve and the drain valve in the water line between heater and boiler check and the drain valve on the bottom of the left end of the heater, if there is one, and also the valve in the condensate line under the cab. This will remove the water from the heater and all pipes except the suction line and the pump. The steam from the heater valve will protect them. Open drains on both steam and water cylinders.

THE LOCOMOTIVE OPEN TYPE FEED-WATER HEATER PRINCIPLE OF OPERATION

The principle of operation of the Open Type Feedwater Heater can be compared to that of any simple water pumping system. Water is pumped from the tender to the feedwater heater by a low pressure low speed centrifugal pump and the amount that is pumped into the heater is controlled by a ball float in the heater. The water is mixed with exhaust steam, in the heater, by spraying it into a body of exhaust steam and it then flows to the hot water reciprocating pump which pumps it into the locomotive boiler.

GENERAL DESCRIPTION

For a general understanding of the feedwater heating equipment arrangement refer to Fig. 70.

The cold water pump unit consists of a Steam Turbine and a Centrifugal Pump combined in one casing. The usual speed of this pump when running at full capacity is about 3600 RPM; the steam which runs this pump is controlled by the float in the feedwater heater. The pump is lubricated by oil located in a storage oil cellar between the bearings and should be changed every three months.

The cold water pump stuffing box should have a slight water leak and the pump shaft should spin freely with finger when pump is not running. If the stuffing box is pulled up too tight it may bind the pump shaft.

Exhaust steam enters the feedwater heater through a group of exhaust check valves, and mixes with water coming through the spray valve. Water and steam mix in the approximate proportions of five to one (five parts water, one part steam). As the heater fills with water, the ball float is lifted, which in turn reduces or shuts off entirely the live steam which operates the cold water centrifugal pump.

The hot water pump is the only high pressure part of the system, and being a long stroke pump, it handles exceedingly hot water without difficulty. The principle of pumping water with a reciprocating pump is similar to pumping air with a reciprocating air pump. Both types of pumps have suction (receiving) and discharge (delivery) valves, and both types are double acting, taking and delivering water or air from both sides of the piston.

The drifting control valve is bolted directly to the steam end of the hot water pump, and all the steam which runs the pumps must first pass through this valve. If locomotive is standing or drifting with little or no steam in cylinders, the drifting control valve opening is restricted, slowing down the hot water pump. If locomotive is using steam in cylinders, and there is over 90 lbs. in steam pipe to cylinders, the drifting control valve is fully opened, the restriction is removed, and hot pump will operate as fast as desired, controlled only by opening in pump operating valve.

The operation of this drifting control valve is accomplished by means of steam flowing through a copper pipe connection between locomotive steam pipe and drifting control valve body. Hot pump speed and cold pump gauge pressure are approximately doubled when drifting control valve is moved from closed to open position.

The cab gauge is connected to the cold water pump discharge pipe, and registers the pressure developed by the cold pump, in delivering water to the heater. This pressure is a combination of three resistances. (1) The resistance of raising water from tender level to feedwater heater. (2) Resistance created by the friction in discharge pipe, line check valve, and spray valve. (3) Resistance of locomotive exhaust steam pressure in feedwater heater against which the water is delivered. A change of pressure indication on the cab gauge does not indicate a change in the capacity at which the pumps are delivering water, but may only indicate a change in the locomotive exhaust steam pressure in the heater. Regardless of a change in gauge pressure, unless the pump throttle position is changed, or unless the drifting control valve opens or closes, there will be no change in the water pumping rate. Since the gauge indicates the cold pump discharge pressure, gradual movements of the gauge hand indicate changes in cold water pump pressure caused by a change in cold water pump speed. Since the cold pump pressure increases when the back pressure of the locomotive increases, the gauge will register roughly some 4 lbs. to 12 lbs. above the back pressure in the heater, depending on the amount of water being pumped.

The hot water pump obtains its lubrication from a mechanical lubricator on the side of the locomotive. Water and steam conditions, as well as the size equipment, dictate the quantity of oil required.

The suction hose anti-freeze valve is conveniently located in the cab and is used in cold weather to provide a small amount of live steam, and direct it to the exposed portion of the equipment, to prevent freezing. This pipe has two branches, one which goes to the cold pump suction strainer box and one which goes into the cold pump discharge pipe. Both have ⅛-in. chokes at point where they attach to strainer box and discharge pipe.

Corrosive oxygen and other undesirable non-condensible gases are separated from the feedwater, and escape from the feedwater heater through vent pipes; one pipe running close to the front of locomotive stack, and the other running to the track under locomotive ashpan.

A small vent cock is attached to the gauge line in locomotive cab, and can be opened for venting air or steam vapor from the cold pump suction when priming cold water pump with water.

OPERATING INSTRUCTIONS

The pumping system should be started as soon as the locomotive throttle is opened, and the water pumping rate then regulated until both locomotive and pumps are working at a steady rate. In heavily treated water districts, where anti-foam compounds are used, prompt opening of the pump operating valve when locomotive throttle is opened, gives the anti-foam compound quick delivery to the boiler which will assist in preventing water raising in the boiler. Water should be fed to the boiler at the same rate it is being evaporated from the boiler, and a pump throttle position which satisfies this condition can be found by a small amount of experimenting with pump operating valve position. The pump gauge does not indicate the quantity of water being pumped, but it does indicate when the pumps are working.

All valves in the system should be in proper working position, such as tank valve, boiler check, steam turrent valve, etc. Lubricator should be feeding oil at a rate which is generally found to be satisfactory. Open cold pump air vent cock in cab to prime pump with water. If it is cold weather and suction anti-frost valve is open, close this valve before starting pumps —but crack it open again as soon as pumps have been started and are pumping water.

In order to get pumps started promptly, open pump operating valve one-half turn, and as soon as cab gauge indicates pressure, regulate pump throttle opening to that position which feeds water to the boiler at the desired rate. When starting up equipment, some seconds will elapse between opening of pump throttle and the indication of pressure on the cold pump gauge. This is because the hot pump must start first, and take some water from the heater, lowering the heater water level, causing the float to open steam control valve, and start the cold pump.

During running test, previous to locomotive leaving terminal, the sound of cold pump, and the pressure on cab gauge, will rise and fall slightly and periodically, indicating the float control in heater to be working normally.

The amount of water pumped is entirely under control of the fireman and by proper adjustment of the pump throttle, any capacity rate can be obtained, while locomotive is working steam in cylinders.

When locomotive throttle is closed, the amount of water pumped to the boiler is automatically reduced to one-half, This reduction in pump capacity is caused by the "Drifting Control

Valve." The pumps can still deliver more water than the boiler is evaporating because locomotive throttle is closed and very little steam is being used. This feature is usually found to be very desirable for locomotive operation which requires a number of short station stops. The quantity of water being automatically reduced during these periods relieves the fireman of this operation and prevents slugging the boiler with water which has not been thoroughly preheated.

Operation of the heater and pumps day after day will soon suggest other operating details which are advantageous. Under certain conditions it is found to be desirable to further reduce pump capacity each time the locomotive throttle is closed by reducing the pump operating valve opening to one quarter turn or less. When locomotive throttle is again opened, the pump valve can again be opened to running position. This method of operation produces the greatest heat saving because the greater percentage of water is pumped through the heater while there is exhaust steam available from the locomotive cylinders for heating.

Heaters that have been applied in recent years have been designed with ample capacity to more than supply the locomotive boiler requirements. They have sufficient over capacity so that not only can they replace water that is being evaporated from the boiler, but also they can raise the boiler water level at the same time if desired. Since there is a large quantity of exhaust steam available while ascending grades, it is customary to pump as much water as possible at this time, and when the top of grade is reached there will be sufficient water in boiler to show in water glass after locomotive has tipped the grade and started down the other side.

If cold water pump runs at an extremely high speed, and gives off a high vibrating tone, pump is not getting water. Tank valve may be closed, tank strainer may be dirty, tender may be empty, tank hose lining may be loose and plugging inlet to pump, or pump may be airbound or overheated with steam from anti-freeze valve.

If pump is airbound, stop pump, open drain cocks beneath pump and ahead of line check valves. Also open cold water pump vent cock. Drain cocks must be open long enough to let all vapor out of pump casing while pump is not running, to permit pump to completely and properly fill with water.

COLD WEATHER PRECAUTIONS

During freezing weather keep the anti-freeze pipe valve cracked open at all times, except when pumps are to be started. Previous to starting pumps, close the anti-freeze valve and when pumps have started and are pumping water, the anti-freeze valve should again be cracked open. This results in the anti-freeze pipe being protected and also in furnishing a small amount of heat to the cold pump at all times.

During long drifting periods of the locomotive, the anti-freeze valve should be opened at least one-half turn and the pump throttle should be cracked open to keep hot water pump creeping. In the event that something occurs to the system which prevents engineman from using it to pump water, procedure as outlined above should be followed, and in addition all drain cocks on hot water pump should be opened.

If after a very long drifting period it is found that the suction hose has been overheated and pump will not handle water, shut off pumps, close anti-freeze valve for a short period and open "Cold Water Pump Air Vent Cock" in gauge line in cab. This will vent all steam vapors and pump will prime with water, after which pumps can again be started.

The anti-freeze valve should always be left open if locomotive is to stand outside unprotected in cold weather. If the weather is severely cold, the pump throttle should also be cracked open. This last protective measure should be followed in cold weather of any severity, if hot pump is on front deck of locomotive.

In the case of a locomotive which has its fire dumped or put out, either on the road or at a terminal, and the locomotive is to remain outside for a period long enough to permit boiler to get cold, the pumping system should be thoroughly drained. All drain cocks should be opened and investigated to see that they are not plugged with dirt. If equipment is drained while boiler is hot, extra care must be taken to prevent leaky boiler checks from permitting water to leak from boiler into pump.

ENGINEERS' WORK REPORTS

Engineers' reports should state as clearly as possible what troubles, if any, are encountered on the road, and if cause of trouble is known it should be reported. If not known, then trouble should be carefully described in work report. If pumps performed satisfactorily under some operating conditions but not under other operating conditions, this fact should be included in report. Usually a pump machinist must work on the pumping system while locomotive is cold, and the more definite a report is, the easier it becomes to find the trouble. Pipe leaks, loose clamps, leaking gaskets, should all be included in a report.