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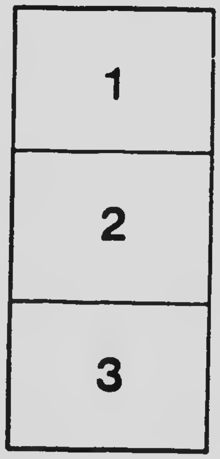

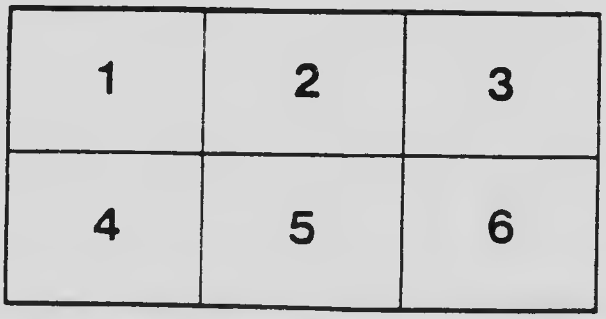

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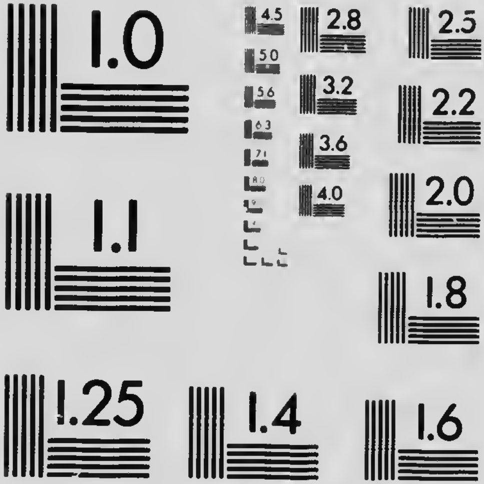

THE

HEATH BOOK

FOR

THRESHERMEN

A BOOK OF INSTRUCTIONS FOR TRACTION AND STATIONARY ENGINEERS, WITH QUESTIONS AND ANSWERS, USEFUL TABLES AND RULES.

PUBLISHED BY

E. H. HEATH CO. LIMITED

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CONTENTS.

PREFACE.

This book is prepared principally from lecture and instruction notes which the author has prepared and used for twelve years, in his work as Instructor in Power Machinery, Minnesota School of Agriculture; in Creamery Engineering in the Minnesota Dairy School; and Farm Mechanics in the School of Agriculture Short Course. These notes have been made up from reviewing various works on the subject, such as "Manual of Steam Boilers" by Thurston, "Catechism of the Locomotive" by M. N. Forney, "Farm Engines and How to Run Them" by Jas. H. Stephenson, "The Traction Engine" by J. H. Maggard, and "Power Catechism" by Power Publishing Co.; also from practical experience and observation with farm engines in the field, and with stationary engines and boilers. It has been the author's aim to arrange the work in a systematic manner, and make it as plain and practical as possible, in order to meet his requirements in giving instruction on this line to engineers in charge of creamery and traction engines, and to serve as a book of elementary instruction for engineers and firemen. The author desires to express his appreciation for valuable suggestions and efficient service rendered by his assistant, Mr. H. B. White. Many of the cuts are made from original drawings by the author, a few are taken from other works on engineering, and a few from supply catalogues. In the chapter on questions and answers, the most important points are covered, and the questions are such as a boiler inspector would be liable to ask in giving an examination to an engineer for a license to run a traction or creamery engine.

DEFINITIONS.

A few definitions are given in order that the engineer may understand some of the common terms used in explaining the work of steam engines and boilers.

Area. Area is the extent of any open surface, and is found by multiplying its length by its breadth, if square or rectangular. If the surface is circular, the area may be found by squaring the diameter, which is multiplying the diameter by itself, and multiplying this number by .7854. This rule will apply to any circular surface, no matter what the diameter is.

Circumference. Circumference is the distance around a circle. The circumference is found by multiplying the diameter by 3.1416.

Diameter. The diameter is the distance across a circle or through a sphere passing through its center. Doubling the diameter of a circle will double its circumference, and will increase its area four times.

Radius. The radius is the **distance** from the center of a circle or sphere to one side, or one half of the diameter.

Matter. Matter is anything that occupies space. It is the substance of which all bodies consist, and is composed of molecules and atoms.

Molecules. A molecule is the smallest part of a substance that can exist separately and still retain its composition and properties.

Atoms. An atom is the smallest portion into which matter can be divided. Atoms unite to form molecules, and a collection of molecules forms a mass or body. A drop of water may be divided and subdivided, until each particle is so small that it can only be seen by the use of the most powerful microscope. But each particle will still be water. When the division has been carried on until it is impossible to divide it again without changing its nature, or to the point where if it be divided again it will cease to be water and will be something else, the small particle of water would be a molecule. If the molecule of water be again divided, it will become atoms, and will consist of two atoms of hydrogen gas and one of oxygen gas:—water being formed from hydrogen and oxygen.

Bodies. Bodies are composed of a collection of molecules, and exist in three conditions or forms, as solid, liquid and gaseous.

Solid Body. A solid body is one whose molecules change their relative position with great difficulty, as iron, wood, stone, etc.

Liquid Body. A liquid body is one whose molecules tend to change their relative position easily. Liquids readily adapt themselves to the shape of vessels which contain them, and their upper surface always tends to become perfectly level.

Gaseous Bodies. A gaseous body, or gas, is one whose molecules tend to separate one from another, as air.

Vapor. Vapor is the gaseous form of a substance that is usually solid or liquid, caused by the application of heat to the liquid, as steam.

Heat. Heat is a form of energy, caused by a motion of the molecules composing matter. If the molecules composing matter move slowly, the body feels cold; whereas if the motion between the molecules is rapid, the body feels warm or hot.

Temperature. Temperature is a term used to indicate how hot or cold a body is, or to indicate the velocity of the vibration of the molecules of a body. Temperature is measured by an instrument called the thermometer, which generally consists of a small glass tube with a bulb at one end filled with mercury. Upon being heated, the mercury expands in proportion to the rise of temperature. Thermometers are graduated in different ways. In the Fahrenheit thermometer, which is in general use, the point where the mercury stands when the instrument is placed in melting ice is marked 32 degrees. The point indicated by the mercury when the thermometer is placed in boiling water, in the open air at the level of the sea, is marked 212 degrees. The space between these two points is divided into 180 equal parts, called degrees.

Absolute Zero. Absolute zero is a point about 460 degrees below zero Fahrenheit, and is the point at which the molecules of a body would be at rest.

Absolute Temperature. Absolute temperature is the temperature measured from the absolute zero point.

Heat Unit, or Measurement of Heat. Heat is measured by the effect it produces in a body. The standard heat unit is the amount of heat required to raise the temperature of a pound of water from 62 to 63 degrees, Fahrenheit.

This unit is called the British Thermal Unit, or B. T. U.

Work. Work is the overcoming of resistance of any kind. The measure of work is one pound raised vertically one foot, and is called one foot pound. All work is measured by this standard. The total amount of work is independent of time, whether it takes one minute or one year in which to do it. But in order to compare the work with a common standard, time must be considered.

Horse Power. The common standard to which all work is reduced is the horse power. One horse power is 33,000 foot pounds per minute; or is equal to 33,000 pounds raised vertically one foot in one minute; or one pound raised vertically 33,000 feet in one minute. Or any combination that will when multiplied together give 33,000 foot pounds per minute.

A horse power as figured above, is based upon the amount of work which a horse will do in one hour, walking at an ordinary gait pulling a light load. A horse pulling a loaded wagon, farm machinery, etc., often does more than one horse power of work.

Pressure. In speaking of pressure in connection with engines and boilers, we generally mean the pressure per square inch. When a boiler has 100 pounds steam pressure on it, the steam is pressing on each square inch in the boiler at a pressure of 100 pounds in all directions. Steam gages indicate the pressure on each square inch.

Pressure of Atmosphere or Air. The air or atmosphere which is about us exerts pressure. This pressure varies with the altitude or height. At the sea level the air exerts a pressure of 14.7 pounds per sq. inch. At higher elevations the pressure is less. On very high mountains the pressure is much less. Air may be compressed. If we had a cylinder closed at the bottom, with a tight fitting piston at the top, and we pushed the piston down in the cylinder it would compress the air, and its pressure would rise. Air may be compressed until it becomes a liquid. When air is compressed it gives off heat. Air will also expand. If we had a long cylinder closed at the bottom, a tight fitting piston or plunger near the bottom leaving some air in the lower part of the cylinder, and were to pull the piston or plunger up, the air would expand. Its pressure would then be less. Air will not condense or turn to water as steam will when it becomes cold.

Circulation of Air. Air circulates with heat.

Warm air, being lighter than cold air, rises rapidly through the cold air. This is what gives a draft through a chimney or smoke pipe; it is also what causes air to circulate through a room where a hot air furnace is used. In an ordinary room heated with a stove, the air is generally several degrees hotter at the ceiling than it is at the floor.

Vacuum. A vacuum is a space from which the air has been removed, generally by what is commonly called suction. An absolute vacuum is a space from which the air has been entirely exhausted. A partial vacuum is a space from which a part of the air has been removed. Were we to take a cylinder closed at the bottom, having a tight-fitting piston or plunger in it at the bottom, and pull up on the plunger we would remove the air from the top, and the space between the plunger and the bottom would become a vocuum, or partial vacuum. On an absolute vacuum we would get a pressure equal to the weight of the air which would be 14.7 pounds per square inch at the sea level. The pressure would be less on a partial vacuum, and less at a higher altitude, depending upon the height at which the vacuum was secured.

Water. Water is a colorless liquid and is formed from hydrogen and oxygen, in the proportion of two volumes of hydrogen to one of oxygen; or by weight, two parts of hydrogen to sixteen parts oxygen. The several conditions of water are usually stated as the solid, when ice, the liquid, when liquid, and the gaseous or vaporous, when turned into steam. The ordinary temperature of water as we get it from a well will generally be from 45 to 75 degrees Fahrenheit. At or below 32 degrees Fahrenheit, water is in a solid state, or frozen as ice. At 39 degrees Fahrenheit water reaches its maximum density, or is in its most compact form. If cooled below 39 degrees it expands, and upon reaching 32 degrees it freezes and expands still more. When water is heated above 39 degrees, it also expands. When heated in a boiler or kettle it circulates. The water next the fire on becoming heated expands, is lighter than the cold water, and rises to the top of the boiler. The cold water goes downward to the bottom, giving a circulation throughout the boiler. When the circulation in a boiler is good, the water is nearly all at the same temperature. When water is heated to 212 degrees in an open boiler or kettle, it commences to give off vapor or steam

The water will not become hotter, but will remain at a temperature of 212 degrees until it is all turned into steam.

One cubic inch of water will make about one cubic foot of steam, or will occupy about 1700 times as much space as it occupied as water. One cubic foot of water weighs about 62½ lbs., contains 6¼ gallons, 1728 cubic inches.

A gallon of water weighs 10 pounds and contains 277.27384 cubic inches.

The pressure per square inch which water will give, depends upon the height to which it is elevated. Each foot of elevation will give about .43 of a pound pressure per square inch. A water tank or pipe 100 feet high will give a pressure of 43 pounds. To find the pressure which a tank will give, multiply its height in feet by .43.

The pressure cannot be increased by increasing the size of the tank; it can only be increased by elevating the tank.

One pound per square inch will raise water 2.31 feet in a pipe or tank.

Water will not expand into a vacuum as air will, but will remain in a solid form at the bottom. Water cannot be compressed. When a cylinder is full of water, it will not be possible to force in more, or to compress it.

Were we to stand a pipe in water, having the lower end open and remove the air from the pipe above water, producing a vacuum, the water will rise in the pipe some distance, according to the extent the vacuum was secured. If an absolute vacuum is secured, it will rise to a height of about 34 feet. The rise of the water in the vacuum is due to the pressure of the atmosphere upon the surface of the water outside of the pipe. It will be noted that the pressure of the atmosphere of 14.7 lbs. times 2.31, the height in feet which one pound pressure will raise water, equals 34 feet. Water will not rise higher than 34 feet in an absolute vacuum. On a suction pump where the cylinder is placed above the water, the water is caused to rise by the vacuum and the air pressure. It is not practical to put a pump cylinder more than 25 feet above the water, on account of it being impossible to secure an absolute vacuum with a common pump. The pump will work better by putting the cylinder closer, or even right in the water.

Steam. When water is heated to a temperature of 212 degrees Fahrenheit, it commences to boil and give off vapor called steam.

The temperature of the water and of the steam that is given off in an open boiler will be 212 degrees. The steam in passing off will condense, or turn to water again. As it turns to water it becomes white in color. When in the form of steam it has no color. The white vapor we notice is the steam condensing and turning to water.

If water or steam be confined in a closed vessel or boiler the temperature of the water and the steam will be the same, and the temperature will increase as the steam pressure increases. When the water is heated to boiling and commences to give off steam the temperature is 212 degrees. At a pressure of 5 pounds the temperature will be nearly 227 degrees; at a pressure of 25 pounds the temperature will be nearly 267 degrees; at a pressure of 50 pounds the temperature will be nearly 297 degrees; at a pressure of 100 pounds the temperature will be nearly 337 degrees, and at a pressure of 200 pounds the temperature will be nearly 389 degrees.

In raising steam pressure from the boiling point to 50 pounds gage pressure, the temperature of the water and steam will be raised from 212 to 297 degrees, or 85 degrees. In raising the steam pressure from 50 pounds gage pressure to 100 pounds, the temperature of the water and steam will be raised from 297 to 337 degrees, a difference of 40 degrees. It will be noted that the pressure is raised from 50 to 100 pounds with about half the heat necessary to raise it from boiling to 50 pounds. As the pressure increases, a smaller amount of heat is required to raise the steam pressure.

Fig. 1 is an imaginary illustration of the conditions of ice, water and steam. In A we will suppose we put one pound of ice in the bottom of an open-mouthed cylinder, and place

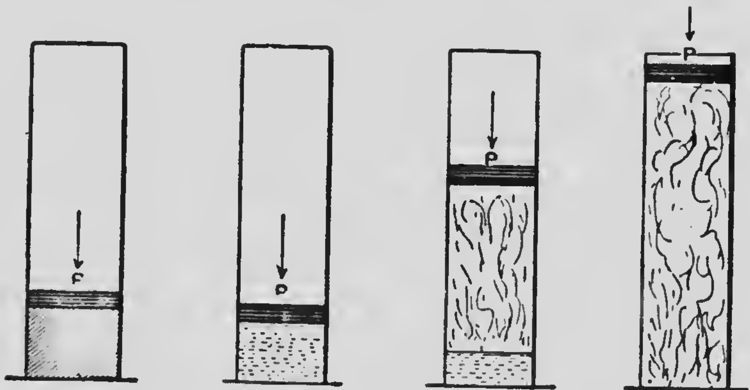


Fig. 1

a tight-fitting piston P on it. On the application of heat at the bottom of the cylinder the ice is gradually heated until it arrives at a temperature of 32 degrees. The temperature will remain at 32 degrees until the ice melts and becomes converted into water. The bulk of the water will be a little less than that of the ice from which it is formed, and the piston descends a very little as at B. After the ice is all turned into water, the temperature of the water will gradually increase until a temperature of 212 degrees is reached, when the water will commence boiling and steam will be formed, the pressure of the steam raising the piston as at C. So long as any water remains at the bottom of the cylinder we are producing what is called "saturated" steam, or wet steam. This is the condition of steam usually supplied to engines from ordinary boilers having the ordinary steam space. When all the water in the bottom of the cylinder has been evaporated, or turned into steam, as at D, we obtain "dry" steam. If heat were continued under the cylinder, the temperature would increase, and we would get what is termed "superheated" steam.

Expansion of Steam. Suppose that steam from a boiler enters a cylinder fitted with a piston, the steam will push the piston ahead of it. Suppose then that when the piston has completed, say, one-half of its stroke, the valve between the boiler and the cylinder is closed, and no more live steam is admitted, the piston will still be pushed by the steam already contained in the cylinder. The pressure, however, will decrease as the piston approaches the opposite end of the cylinder. The work that the steam does in pushing the piston, after it is shut off from the boiler, must come from the heat contained in the steam already in the cylinder. Its temperature must fall with its pressure, as the piston moves out to the end. When steam is shut off from the cylinder in this manner, it does work at the expense of its own heat, and is said to be used "expansively," or "working on expansion."

Condensation of Steam. As the temperature of steam is lowered, the steam will condense or turn into water. If in the cylinder D, Fig. 1, we remove the heat after the water is all turned into steam, the steam will gradually cool and condense, and we will have the reverse action. The steam cooling turns to water, as in C and B. If no steam were allowed to escape around the piston, we would have the same amount of water that we had when we started. Were we to hold the piston at the top in D and allow the steam to condense, the water would settle to the bottom of the cylinder, and the space then between the water and the piston would become a vacuum.

Latent Heat of Steam. Were we to take one pound of water at a temperature of 32 degrees, and apply heat to it, and note the time it took to raise its temperature to 212 degrees, or boiling point, and were we to continue heating it until it was all evaporated or boiled away, it would take 5½ times as long, or 5½ times as much heat, to turn it into steam from 212 degrees, as it did to raise it from the temperature of 32 degrees to 212 degrees. Its temperature would not rise, but would remain at 212 degrees. The heat which we apply to this water after the boiling point is reached is called "latent heat."

Steam Table. The steam table given on pages 26, 27, 28, 29, is a table of the properties of saturated steam, at pressures from 1 to 300 pounds above the vacuum. Whenever the pressure of steam is changed its other properties also change, such as the following:

First. The temperature of the steam, or its boiling point.

Second. The number of heat units required to raise a pound of water from 32 degrees to the boiling point corresponding to the given pressure. This is called the heat of the liquid.

Third. The amount of heat required to change the water at the boiling temperature into steam at the same temperature. This is called the latent heat, or latent heat of vaporization.

Fourth. The amount of heat required to change a pound of water from 32 degrees to steam of the required temperature and pressure. This is called total heat, or the total heat of vaporization. The total heat is the sum of the liquid and the latent heat.

Fifth. The specific volume of steam at the given pressure, or the number of cubic feet occupied by a pound of steam at the given pressure.

Sixth. The density of steam. That is, the weight of one cubic foot of steam at the given pressure.

Explanation of Steam Table. The steam table on pages 26, 27, 28, 29 of the properties of saturated steam, gives the ordinary pressure from 1 to 300 pounds above vacuum. Column 1 gives the pressure shown on the steam gage. Column 2 gives the pressure above the vacuum, called absolute pressure. Column 3 gives the temperature of the steam when at the gage pressure shown in Column 1, or absolute pressure shown in Column 2. Column 4 gives the heat of the liquid. Column 5 gives the latent heat of vaporization. It will be noted that this decreases slightly as the pressure increases. Column 6 gives the total heat of vaporization. The values in Column 6 may be had by adding together the values in Columns 4 and 5. Column 7 gives the weight of a cubic foot of steam in pounds. It will be noted that as the pressure rises the steam becomes denser, and weighs more per cubic foot. Column 8 gives the number of cubic feet occupied by one pound of steam at the given pressure. Column 9 gives the ratio of the volume of a pound of steam at the given pressure and the volume of a pound of water at 39.1 degrees. The values in Column 9 may be obtained by dividing 62.425, the weight of a cubic foot of water at 39.1 degrees, by the numbers in Column 7.

STEAM TABLE.

The Properties of Saturated Steam.

Steam Gage Pressure.	Pressure above Vacuum in lbs. pr. Square Inch.	Temperature Fahrenheit Degrees.	Quantities of Heat in British Thermal Units. Required to Raise Temperature of the Water from 32° to Temperature, Column 3.	Quantities of Heat in British Thermal Units. Total Latent Heat at Pressure Columns 1 and 2.	Quantities of Heat in British Thermal Units. Total Heat above 32°.	Weight of Cubic Foot of Steam in Pounds.	Volume. Of a Pound of Steam in Cubic Feet.	Volume. Of Steam to Vol. of Eq. Wt. of Dist. Water at Temp. of Maximum Density.
1	2	3	4	5	6	7	8	9
(Not recorded by Steam Gage)	1	102.018	70.040	1043.015	1113.055	.003027	330.4	20623
	2	126.302	94.368	1026.094	1120.462	.005818	171.9	10730
	3	141.654	109.764	1015.380	1125.144	.008522	117.3	7325
	4	153.122	121.271	1007.370	1128.641	.011172	89.51	5528
	5	162.370	130.563	1000.899	1131.462	.013781	72.56	4530
	6	170.173	138.401	995.441	1133.842	.016357	61.14	3816
	7	176.945	145.213	990.695	1135.908	.018908	52.89	3302
	8	182.952	151.255	986.485	1137.740	.021436	46.65	2912
	9	188.357	156.699	982.690	1139.389	.023944	41.77	2607
	10	193.284	161.660	979.232	1140.892	.026437	37.83	2361
	11	197.814	166.225	976.050	1142.275	.028911	34.59	2159
	12	202.012	170.457	973.098	1143.555	.031376	31.87	1990
	13	205.929	174.402	970.346	1144.748	.033828	29.56	1845
	14	209.604	178.112	967.757	1145.869	.036265	27.58	1721

1	2	3	4	5	6	7	8	9
0	14.69	212.0.0	180.531	966.069	1146.600	.037928	26.37	1646
0.3	15	213.067	181.608	965.318	1146.926	.038688	25.85	1614
1.3	16	216.347	184.919	963.007	1147.926	.041109	24.33	1519
2.3	17	219.452	188.056	960.818	1148.874	.043519	22.98	1434
3.3	18	222.424	191.058	958.721	1149.779	.045920	21.78	1359
4.3	19	225.255	193.918	956.725	1150.643	.048312	20.7[illegible]	1292
5.3	20	227.964	196.655	954.814	1151.469	.050696	19.73	1231.0
7.3	22	233.069	201.817	951.209	1153.026	.055446	18.04	1126.0
9.3	24	237.803	206.610	947.861	1154.471	.060171	16.62	1038.0
11.3	26	242.225	211.089	944.730	1155.819	[illegible]4870	15.42	962.3
13.3	28	246.376	215.239	941.791	1157.084	.[illegible]9545	14.38	897.0
15.3	30	250.293	219.261	939.019	1158.28[illegible]	.074201	13.48	841.3
17.3	32	254.002	223.021	936.389	1159.410	.078839	12.68	791.8
19.3	34	257.523	226.594	933.891	1160.485	.083461	11.98	748.0
21.3	36	260.883	230.001	931.508	1161.509	.088067	11.36	708.8
23.3	38	264.093	233.261	929.227	1162.488	.092657	10.79	673.7
25.3	40	267.168	236.296	927.040	1163.426	.097231	10.28	642.0
27.3	42	270.122	239.389	924.940	1164.329	.101794	9.826	613.3
29.3	44	272.965	242.275	922.919	1165.194	.106345	9.403	587.0
31.3	46	275.704	245.061	920.968	1166.029	.11[illegible]884	9.018	563.0
33.3	48	278.348	247.752	919.084	1166.836	.115411	8.665	540.9

1	2	3	4	5	6	7	8	9
35.3	50	280.904	250.355	917.260	1167.615	.119927	8.338	520.5
37.3	52	283.381	252.875	915.494	1168.369	.124433	8.037	501.7
39.3	54	285.781	255.321	913.781	1169.102	.128928	7.756	484.2
41.3	56	288.111	257.695	912.118	1169.813	.133414	7.496	467.9
43.3	58	290.374	260.002	910.501	1170.503	.137892	7.252	452.7
45.3	60	292.575	262.248	908.928	1171.176	.142362	7.024	438.5
47.3	62	294.717	264.433	907.396	1171.829	.146824	6.811	425.2
49.3	64	296.805	266.566	905.900	1172.466	.151277	6.610	412.6
51.3	66	298.842	268.644	904.433	1173.087	.155721	6.422	400.8
53.3	68	300.831	270.674	903.[illegible]20	1173.694	.160157	6.244	389.8
55.3	70	302.774	272.657	901.629	1174.286	.164584	6.076	379.3
57.3	72	304.669	274.597	900.269	1174.866	.169003	5.917	369.4
59.3	74	306.526	276.493	898.938	1175.431	.173417	5.767	36[illegible].0
61.3	76	308.344	278.170	897.635	1175.985	.177825	5.624	351.1
63.3	78	310.123	280.170	896.359	1176.529	.182229	5.488	342.6
65.3	80	311.866	281.952	895.108	1177.060	.186627	5.358	334.5
67.3	82	313.576	283.701	893.879	1177.580	.191017	5.235	326.8
69.3	84	315.250	285.414	892.677	1178.091	.195401	5.118	319.5
71.3	86	316.893	287.096	891.496	1178.592	.199781	5.006	312.5
73.3	88	318.510	288.75[illegible]	890.335	1179.085	.204155	4.898	305.8
75.3	90	320.094	290.375	889.196	1179.569	.208525	4.796	299.4
77.3	92	321.653	291.970	888.075	1180.045	.212892	4.697	293.2
79.3	94	323.183	293.539	886.972	1180.511	.217253	4.603	287.3
81.3	96	324.688	295.083	885.887	1180.97[illegible]	.221604	4.513	281.7
83.3	98	326.169	296.601	884.821	1181.422	.225950	4.426	276.3

1	2	3	4	5	6	7	8	9
85.3	100	327.625	298.093	883.773	1181.866	.230293	4.342	271.1
90.3	105	331.169	301.731	881.214	1182.945	.241139	4.147	258.9
95.3	110	334.582	305.242	878.722	1183.986	.25194[illegible]	3.969	247.8
100.3	115	337.874	308.621	876.371	1184.992	.262732	3.806	237.6
105.3	120	341.058	311.885	874.076	1185.961	.273500	3.656	228.3
110.3	125	344.136	315.051	871.848	1186.899	.284243	3.518	219.6
115.3	130	347.121	318.121	869.688	1187.809	.294961	3.390	211.6
120.3	135	350.015	321.105	867.590	1188.695	.305659	3.272	204.2
125.3	140	352.827	324.003	865.552	1189.555	.316338	3.161	197.3
130.3	145	355.562	326.823	863.567	1190.390	.326998	3.058	190.9
135.3	150	358.223	329.566	861.634	1191.200	.337643	2.962	184.9
145.3	160	363.346	334.850	857.912	1192.762	.358886	2.786	173.9
155.3	170	368.226	339.892	854.359	1194.251	.380071	2.631	164.3
165.3	180	372.886	344.708	850.963	1195.671	.401201	2.493	155.6
175.3	190	377.352	349.329	847.703	1197.032	.422280	2.368	147.8
185.3	200	381.636	353.766	844.573	1198.339	.443310	2.256	140.8
195.3	210	385.759	358.041	841.556	1199.597	.464295	2.154	134.5
205.3	220	389.736	362.168	838.642	1200.810	.485327	2.061	128.[illegible]
215.3	230	393.575	366.152	835.828	1201.980	.506139	1.976	123.3
225.3	240	397.285	370.008	833.103	1203.111	.527003	1.898	118.5
235.3	250	400.883	373.750	830.459	1204.209	.547831	1.825	114.0
245.3	260	404.370	377.377	827.896	1205.273	.568626	1.759	109.8
255.3	270	407.755	380.905	825.401	1206.306	.589390	1.697	105.9
265.3	280	411.048	384.337	822.973	1207.310	.610124	1.639	102.3
275.3	290	414.250	387.677	820.6[illegible]9	1208.286	.630829	1.585	99.0
285.3	300	417.371	390.933	818.305	1209.238	.651506	1.535	95.8

STEAM BOILERS.

A steam boiler is a vessel in which steam is generated to be used for power or heating purposes, and usually consists of the following parts: The furnace, in which the burning or combustion of the fuel takes place; a part to contain the water to be turned into steam; and a place for storage when the steam is generated. They are made in many forms. Often for low pressure or heating boilers, they are made of cast iron. Boilers for power purposes are generally made from iron or steel. The iron or steel for power purposes should have a tensile strength of from fifty to sixty thousand pounds per square inch. Tensile strength means the pulling strength required to break a bar one inch square.

The safe working pressure of a steam boiler depends upon its diameter, the thickness of its shell, the manner in which the seams are riveted, the kind of material from which the boiler is constructed, and the condition of the boiler, as to whether it is rusted or pitted and is not of its original thickness.

The seams of a boiler are, of course, weaker than any other part, on account of part of the material being cut out in making holes for the rivets. On a single riveted boiler it is customary to allow only about 56 per cent of the tensile strength of the material. On a double riveted boiler it is customary to allow about 70 per cent of the tensile strength of the material. On the better class of boilers often there are three or more rows of rivets, and often on the best class of boilers the edges of the sheets butt together and a strap is riveted on each side of the joint. Such a joint is called a butt and strap joint. When well made with the proper size rivets, the efficiency of this joint may reach above 90 per cent of the tensile strength of the material.

In threshing or creamery boilers the longitudinal seams, or seams running lengthwise of the boiler, are generally double riveted. The girth seams, or seams running around the boiler, are generally single riveted. The girth seams are not subject to as much pressure as the longitudinal seams.

A large boiler must have a thicker shell than a small one in order to stand the same pressure. The thickness of a boiler shell must increase in the same ratio that the diameter increases. A boiler 24 inches in diameter ¼ of an inch thick, will stand twice the pressure of a boiler 48 inches in diameter ¼ of an inch thick, or the 48 inch boiler would need to be ½ inch thick in order to stand the same pressure as the 24 inch boiler ¼ inch thick. The pressure in a steam boiler is equal in all directions, and a 48 inch boiler would have twice as many square inches in its shell as a 24 inch boiler, consequently it must be twice as strong in order to stand the same pressure. The length of a boiler is not considered in figuring its safe working or bursting pressure, as it is the longitudinal seams that are required to stand the greatest pressure.

Boiler iron or steel should have a tensile strength of from fifty to sixty thousand pounds. This means that a bar of the material from which the boiler was made, one inch thick, must stand the pulling strain of that amount. A bar ½ inch thick and 1 inch wide, would stand one-half of that amount. A bar ¼ of an inch thick and 1 inch wide would stand one-quarter that amount.

The tensile strength of boiler plate is found by testing a piece of it in a testing machine, and the tensile strength of the material is usually stamped upon the plate. It is customary to allow one-sixth of the bursting pressure of boiler material as a safe working pressure.

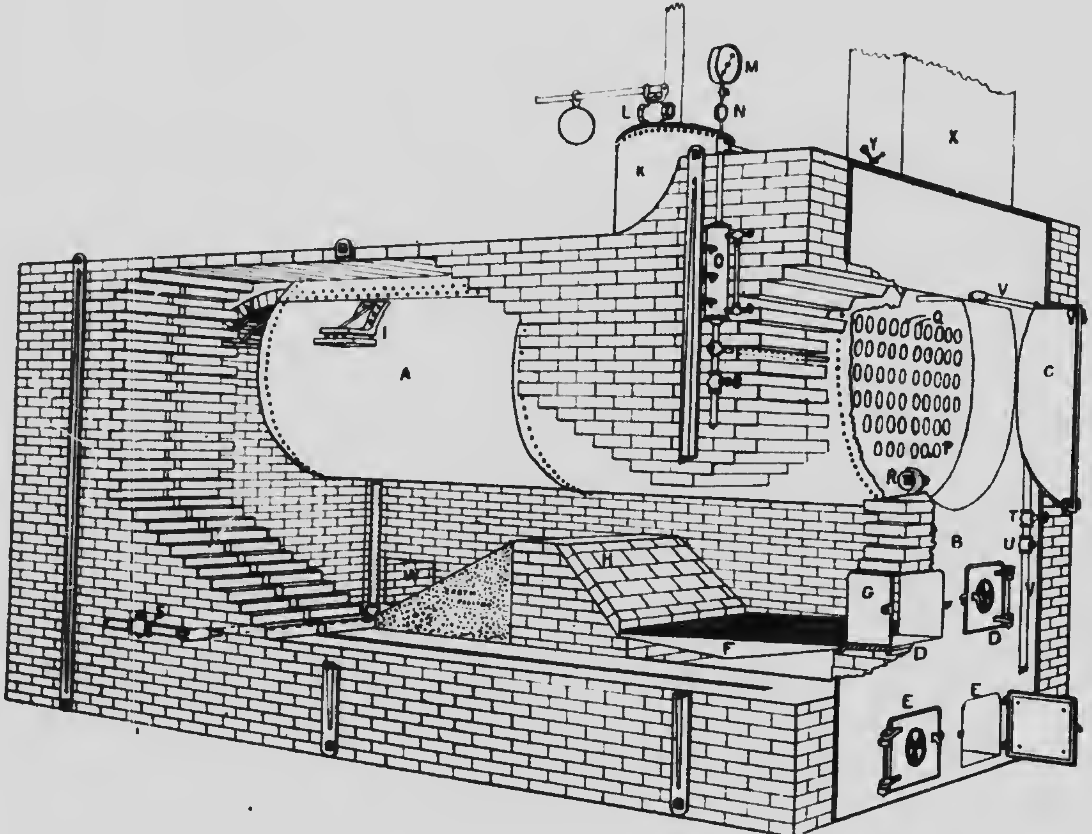
Test strips of the material should stand bending double while hot, also while cold, and after having been heated to a bright red heat and quenched in cold water.

To find the bursting pressure of a cylindrical boiler, multiply the tensile strength of the shell by its thickness in inches. If the boiler be double riveted, multiply this by 70 per cent to find its strength at the riveted joint. Divide this by the radius, or one-half of the diameter of the boiler. To find the safe working pressure, divide this by six.

Example: Diameter of boiler 36 inches; thickness of shell ¼ inch; tensile strength 60,000 pounds; seams double riveted. What is the bursting pressure, and the safe working pressure?

60,000 multiplied by ¼ inch (thickness of shell) equals 15,000. 15,000 multiplied by 70 per cent equals 10,500. 10,500 divided by 18 inches (radius of boiler) equals 583 pounds, bursting pressure.

583 pounds divided by 6 (factor of safety) equals 97 pounds, safe working pressure.



A—Boiler.
B—Front.
C—Flue Door.
D—Fire Door.
E—Ash Door.
F—Grates.
G—Door Liner.
H—Bridge Wall.
I—Bracket and Rollers.
J—Back Arch.
K—Dome.
L—Safety Valve.
M—Steam Gage.
N—Steam Gage Syphon.
O—Water Column.
P—Tube Sheet.
Q—Tubes.
R—Hand Hole.
S—Blow Off Valve.
T—Hand Stop Valve.
U—Check Valve.
V—Boiler Feed Pipe.
W—Clean Out Door.
X—Smoke Pipe or Britchen.
Y—Damper.

Fig. 2.

Horizontal Boilers. Figure 2 shows a horizontal return tubular boiler set in brick work, which is a form in common use in creameries and small stationary plants. It is probably the best boiler for such places, being economical of fuel, easily managed and cleaned. Because of its cylindrical form the greater part of the dirt and sediment will settle at the bottom where it may be easily scraped and washed out through the hand-hole (R) and blow-off (S).

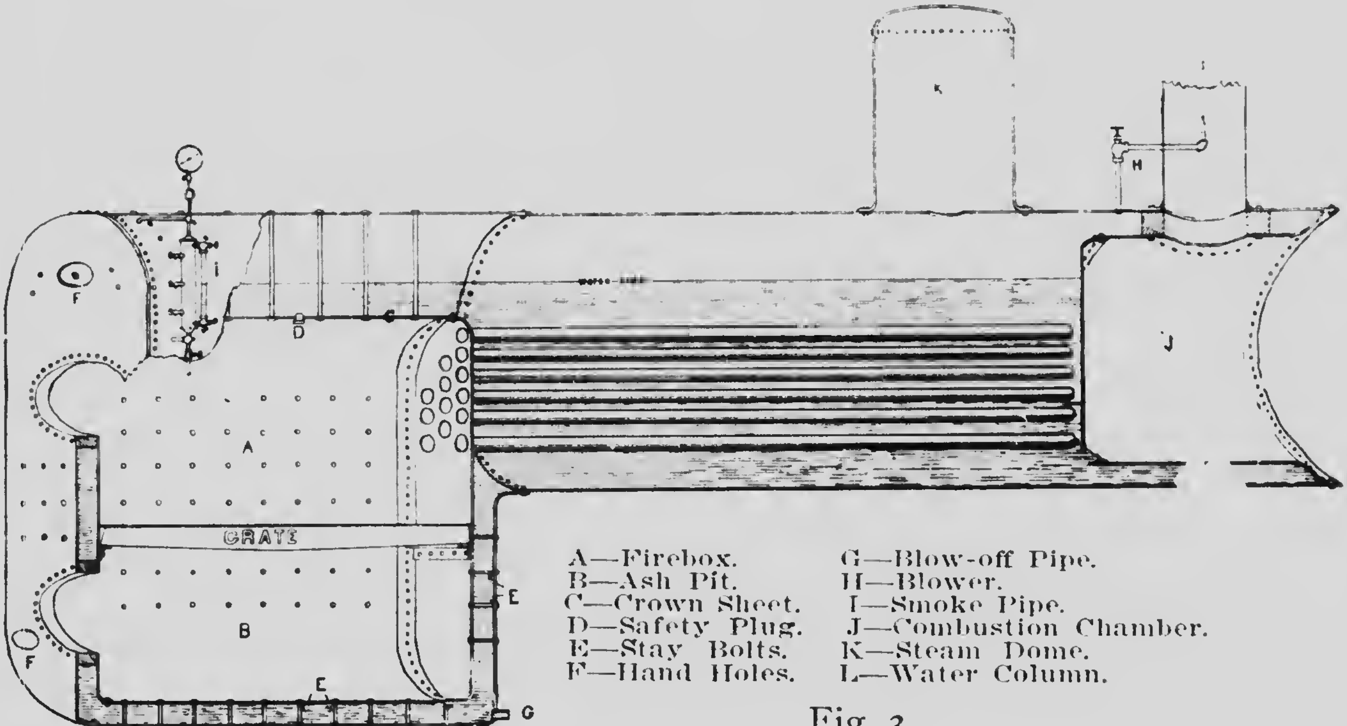
These boilers range in size from about 8 to 150 horse power. Owing to their form, no stay bolts and but few braces are required in boilers of this type. The tube sheets and top of the dome being the only flat places, are all that require braces. The tubes which extend from end to end act as braces for the tube sheets in the water space. Solid braces are put above the tubes running from the tube sheets to the top side of the boiler; also from the top to the sides of the dome.

Boilers of this type are not so liable to serious damage from low water as many other types. As long as there is any water in the boiler it is over the fire or hottest part. The first damage that is liable to occur is from the tubes being burned at the rear end, should the water become low.

These boilers are usually supported by brackets riveted to the sides of the boiler and resting on the side walls. The brackets at the rear end should rest on three or four iron rollers about one inch in diameter and eight inches long. The rollers in turn should rest upon a cast iron plate, set in the brick wall. The object of the rollers is to allow the boiler to expand and contract without cracking the brick work. Proper allowance should also be made for the boiler expanding and contracting at the rear end, by leaving the brick a short distance away from the end of the boiler and filling the space left with some material that will allow the boiler to get longer and shorter without pushing out the end wall. Boilers of large size are often supported by iron posts set on each side of the boiler, extending up two or three feet above the boiler, and the boiler hung from a girder placed upon these posts. The brick work is then filled in around the posts and serves simply to make a fire box and combustion chamber. This makes a much better arrangement for setting a boiler, there being no danger from the boiler settling, and the walls may be repaired without interfering with the boiler setting.

With this boiler the fire passes under the boiler and returns through the tubes to the front end, and then up through the breeching or smoke pipe to the chimney.

The furnace should be lined with fire brick, which are special brick that will stand heat. This lining extends from the surface of the grates up to where the brick closes in on the side of the boiler. Fire brick should be laid in a thin mortar made from fire clay and water, just enough to fill up the irregularities of the surface and give them a solid bearing. In laying the fire brick, each one should be dipped into water as used, so as not to take the water from the mortar too rapidly. Every sixth row of brick beginning at grate surface should be of headers, well bonded into the wall behind, so as to allow the brick work to be repaired when burned out. The arch over the fire door should be made from arch fire brick. These are brick made for the purpose, which are thinner in one end or wedge shaped, and would naturally stay in position should the fire clay become loose and fall out. The side and rear walls should always be double with a two inch air space between them, as shown in cut. The object of the air space is to prevent leakage of heat as much as possible. The walls should not be bonded together, but projecting brick



A—Firebox.
B—Ash Pit.
C—Crown Sheet.
D—Safety Plug.
E—Stay Bolts.
F—Hand Holes.
G—Blow-off Pipe.
H—Blower.
I—Smoke Pipe.
J—Combustion Chamber.
K—Steam Dome.
L—Water Column.

Fig. 3.

from the outer wall should extend to the inner wall. This leaves the inner wall free to expand without affecting the outer wall.

This type of boiler is no doubt the best boiler to be had for creameries and moderate sized steam plants.

Fire Box Boilers. The fire box boiler shown in Figure 3 is a type of boiler that is used to quite an extent in locomotives, some threshing engines, and for stationary boilers where it is desirable to have a boiler which is self-contained and where the brick work may be dispensed with. In many cases they are mounted upon skids, and are largely used in gas and oil well regions, also for portable sawmills where it is desirable to have a boiler that may be moved frequently. There are many good points in its favor, it being easily moved, requiring no expensive brick setting, and occupying small space. It is fairly economical of fuel, although not equal in this respect to the horizontal return tubular boiler. It is more liable to leakage owing to unequal expansion and numerous joints and braces.

Owing to its construction it is not so easily cleaned as a horizontal tubular boiler, as the dirt and sediment settle on the crown sheet and on the bottom, both of which have numerous stay bolts which obstruct scraping and washing. This may be called an internal fire boiler, the fire being inside of the fire box and the heat passing through the tubes to the smoke pipe.

Boilers of this type are more liable to serious damage should the water become low, as in that case the water would leave the crown sheet bare. The crown sheet being immediately over the hottest fire, it would soon become dangerously overheated.

Vertical or Upright Boilers. Vertical or upright boilers, shown in Figure 4, are generally used in places where a small boiler is required and floor space is limited. They are not economical of fuel, the tubes being vertical will not retain the heat as well as a horizontal tube. Owing to the fact that heat always rises, in a vertical boiler it tends to pass out quickly, and is not impinged against the tubes as in a horizontal boiler.

It is not a durable boiler, and is hard to clean and keep in repair. The dirt and sediment settle on the tube sheet directly over the fire. The tube sheet being filled with tubes is very difficult to clean, and if not kept clean

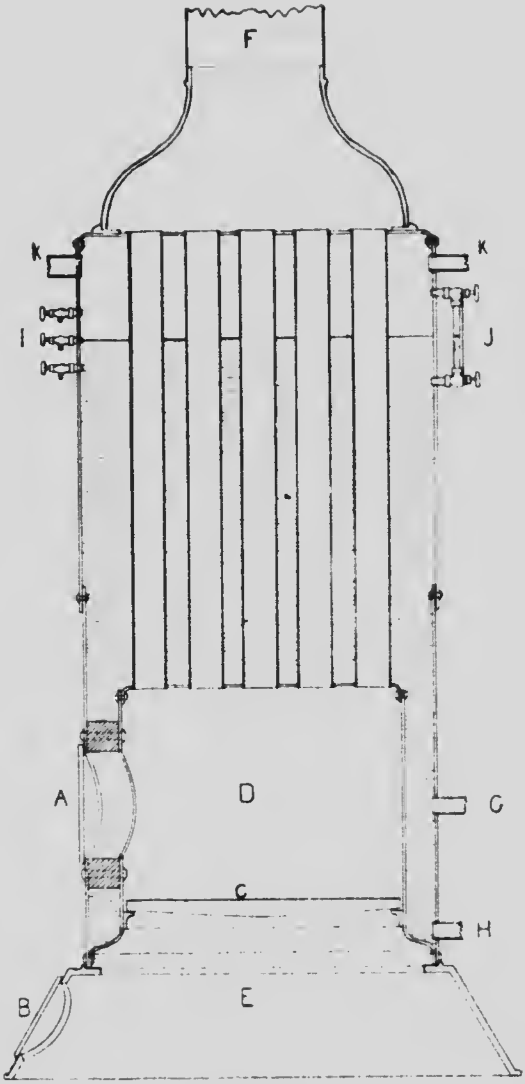


Fig. 4.

A—Fire Door.
B—Ash Door
C—Grate.
D—Firebox.
E—Ash Pit.
F—Smoke Pipe.
G—Feed Pipe.
H—Blow Off Pipe.
I—Gage Cocks.
J—Glass Gage.
K—Steam Pipes.

Fig. 5.

A-Firebox.
B-Grates.
C-Ash Pit.
D-Tubes

E-Steam and Water Drum.
F-Water Column.
G-Damper.

H-Mud Drum.
I-Fire Door.
J-Ash Door.
K-Steam Pipe.

it and the tube ends become overheated, which makes it dangerous and liable to leak. It will be noticed in the cut that the upper ends of the tubes extend above the water line. They are also made in what is called the "Submerged tube," in which the upper tube sheet is lowered down below the water line. By this method the entire tubes are covered with water. Boilers of this type are not to be recommended except where it is desirable to use them for a short time or for a small amount of work.

Water Tube Boilers. Water tube boilers are often used in large steam plants, where boilers of great size carrying a very high steam pressure are desired. Figure 5 shows the water tube boiler, of which there are several makes. The one shown is of the Babcock & Wilcox type.

Water tube boilers are composed principally of wrought iron tubes about 4 to 6 inches in diameter, arranged in sections connected at each end with a steam and water dome above them. These tubes are generally placed at an incline, and are entirely filled with water, the water extending up into the steam and water drum. In these boilers the water is on the inside of the tubes and the heat on the outside.

The water inside the tubes when heated has a tendency to rise toward the higher end, and upward into the steam and water drum where the steam is given off. The back connections permit a downward current, and thus a continuous circulation is obtained.

Boilers of this type are safe where a very high pressure is carried, owing to the small size of tubes. These boilers range in size up to several hundred horse power, and often carry steam up to 250 pounds pressure. Boilers of this kind are only recommended for large plants, and for such work are very desirable. They are quite safe from explosions, as an explosion in a boiler of this kind generally consists in the rupture of a tube which would release the water and steam comparatively slowly, and would not do the damage that would be caused by a large boiler bursting open. They are quite economical of fuel, but require closer attention than the horizontal return tubular boilers.

Traction Engine Boilers. Boilers for traction engines are usually constructed so as to burn either straw, wood or coal. For burning straw a change is generally necessary in the furnace, such as putting a brick arch in the fire box type, or an extension on the back end of the return flue boiler, so as to give the burning gases a longer distance to travel in passing through the boiler, and to provide more space for the straw being fed into the furnace. It also prevents the burning straw from lodging against the ends of the tubes and clogging them up. Traction engine boilers are made in several types, each of which has its particular points of favor. Good results are easily obtained from each type when properly managed. Figures 6 to 11 are those in most common use.

Return Flue Boiler. Figure 6 shows the side and end view of a return flue boiler for traction engines, fitted for burning wood and coal. Both shell and main flue are round. The fire is in the main flue, passes to the front end, and returns through the tubes at the sides and above the main flue. There is a free circulation of water all around the main flue. A boiler of this kind has an advantage in that it is quite easily cleaned, as much of the dirt and sediment settle to the bottom where it may be washed and blown out. The cut also shows a super-heater pipe which takes the steam from the top of the dome, carries it back through the dome on the inside near the top of the boiler out through the rear head into the

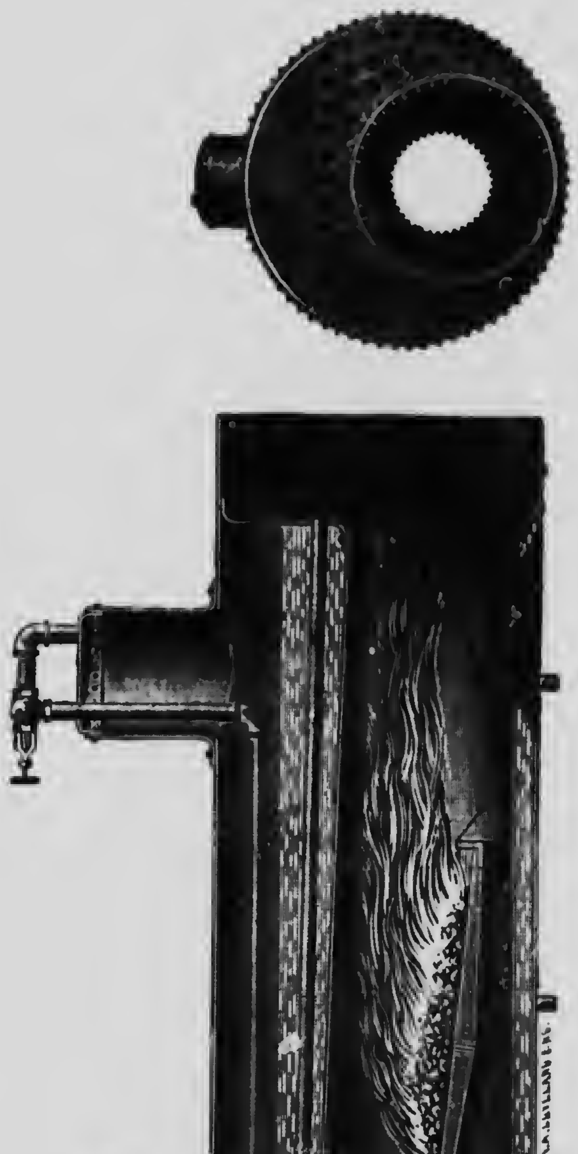


Fig. 6.

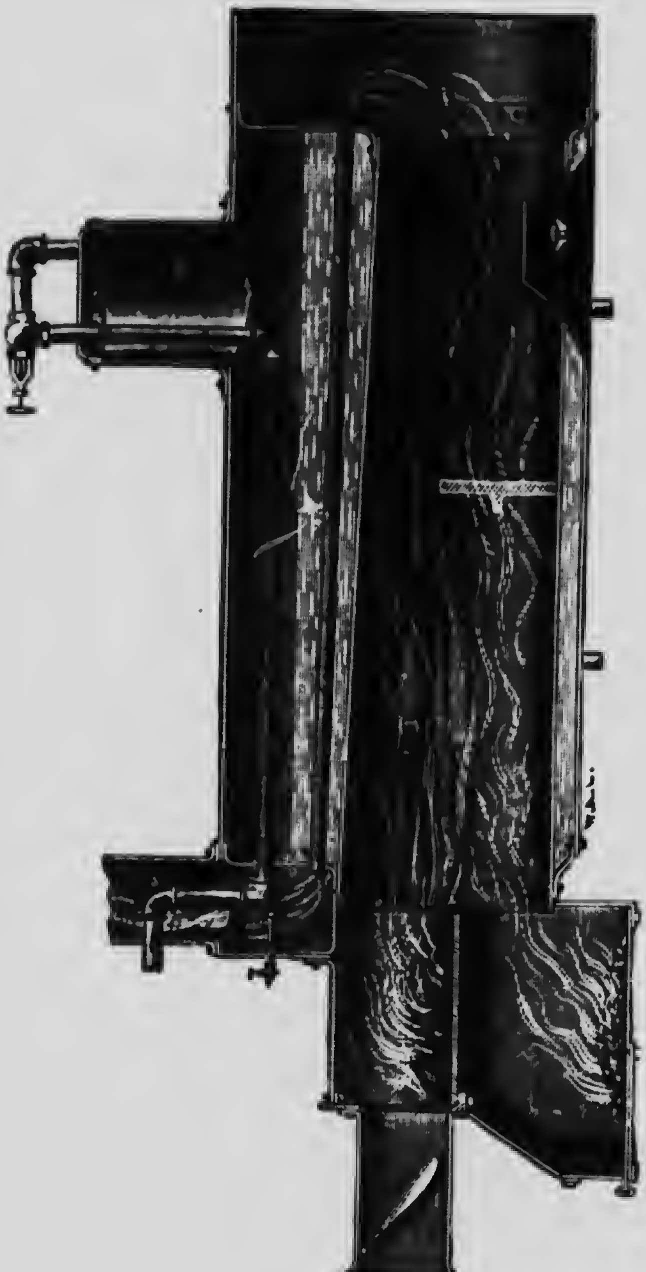


Fig. 7.

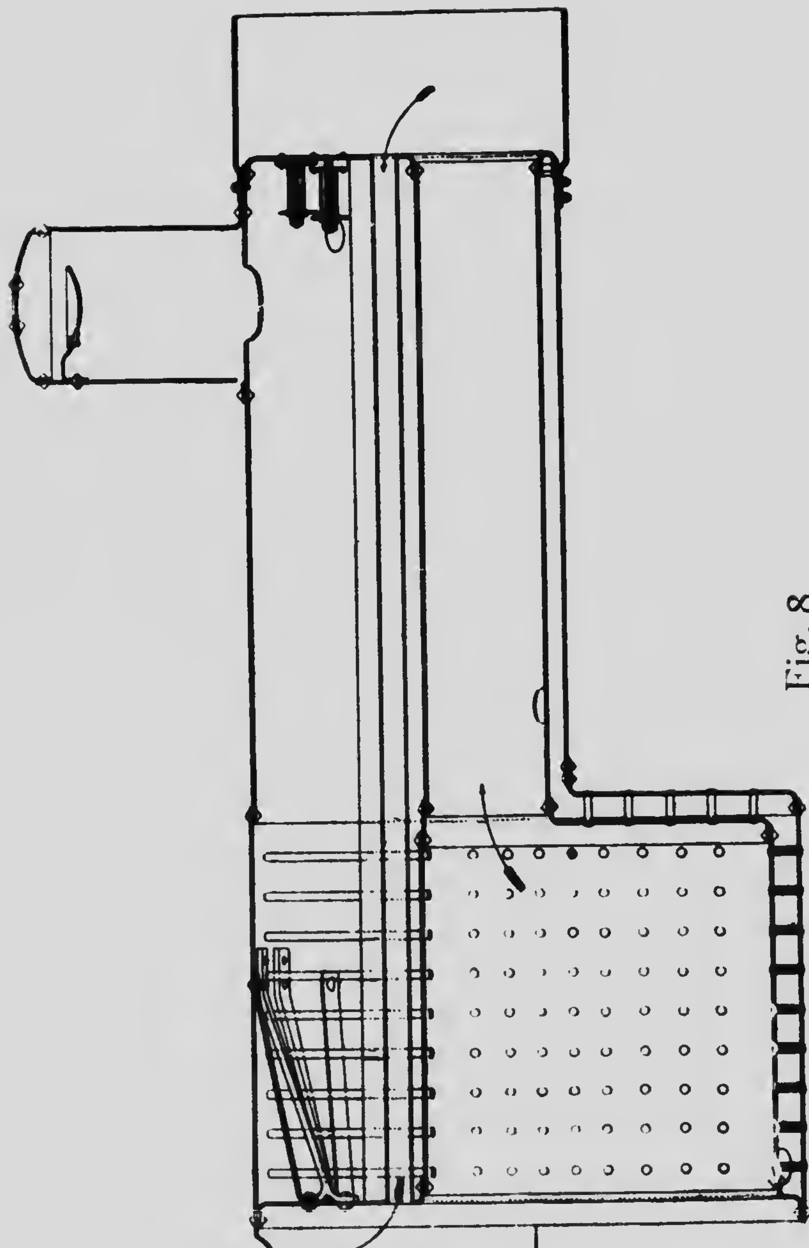


Fig. 8.

smoke box; then up through the smoke pipe and into the steam chest of the engine. It is exposed to the air only a few inches which keeps the steam from condensing before it reaches the steam chest of the engine. A pet-cock is put at the rear end to drain out any water that should condense. There is also a drip hole in the lower part of the pipe to drain water into the boiler. A large valve is placed on the steam pipe at the top of the dome to shut the steam off entirely.

Figure 7 shows a side view of the same boiler fitted for burning straw. It will be noted that there is an extension added to the rear end, with short grates and a self-closing door where the straw is fed in. This door closes from its own weight and prevents cold air being drawn into the furnace.

Fire Box Return Flue Boiler. Figure 8 shows a side view of a fire box return flue boiler. Figure 9 shows the end view of the same boiler. The grates on this boiler are not shown. The fire is in the fire box, the heat passing through the flue and then returning through the tubes above and at the sides of the flue.

Fire Box Boiler. Figure 10 shows a fire box boiler fitted for burning straw. This boiler is fitted for burning straw by putting in the fire brick arch "A." Part of the regular grates are covered by the dead plate "J." It will be noted that the air passing into the fire

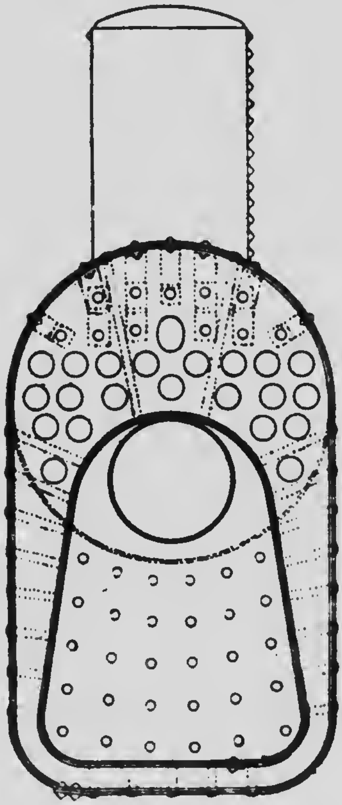
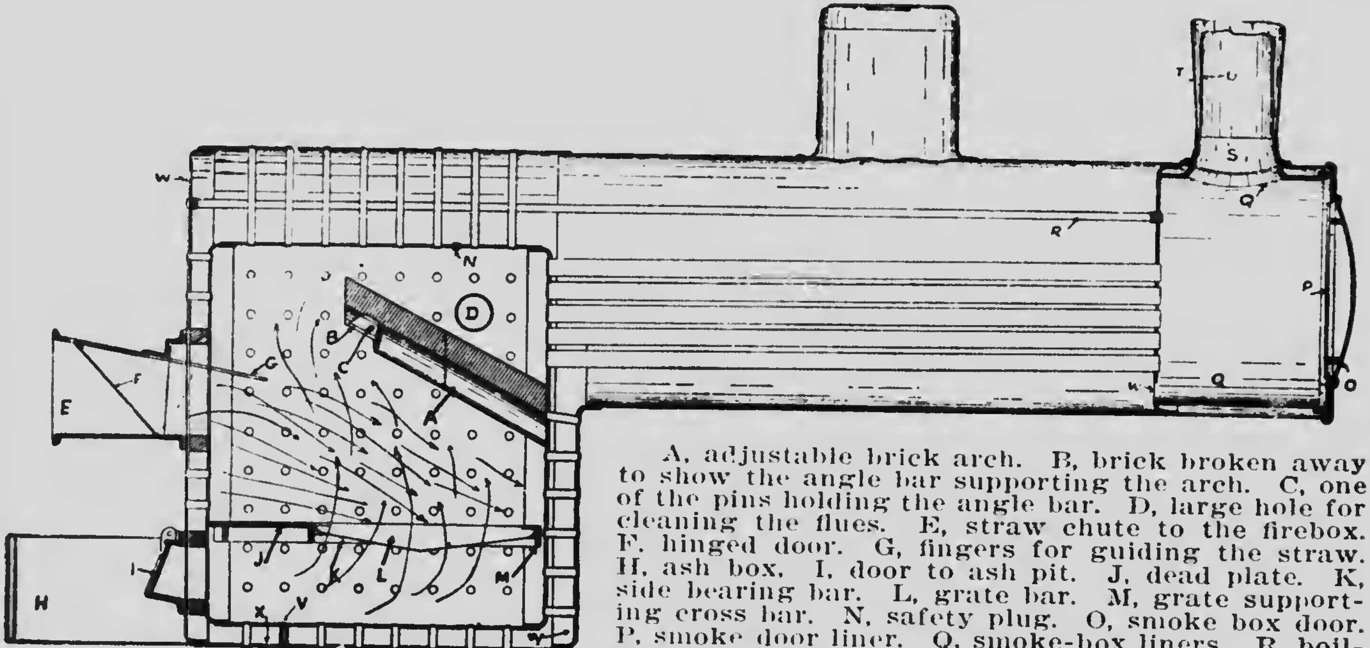


Fig. 9.

box draws against the burn[illegible] straw. The fire brick arch prevents the burning straw from being carried directly up against the tubes, also gives the flame or heat a longer distance to travel in passing through the boiler.



A, adjustable brick arch. B, brick broken away to show the angle bar supporting the arch. C, one of the pins holding the angle bar. D, large hole for cleaning the flues. E, straw chute to the firebox. F, hinged door. G, fingers for guiding the straw. H, ash box. I, door to ash pit. J, dead plate. K, side bearing bar. L, grate bar. M, grate supporting cross bar. N, safety plug. O, smoke box door. P, smoke door liner. Q, smoke-box liners R, boiler head stay rods. S, heavy cast-iron stack base. T, outside shell of smoke stack. U, inside shell or liner of smoke stack. V, ash pit drain hole. W, hand holes. X, boiler drain hole **Y, blow-off.**

Fig. 10.

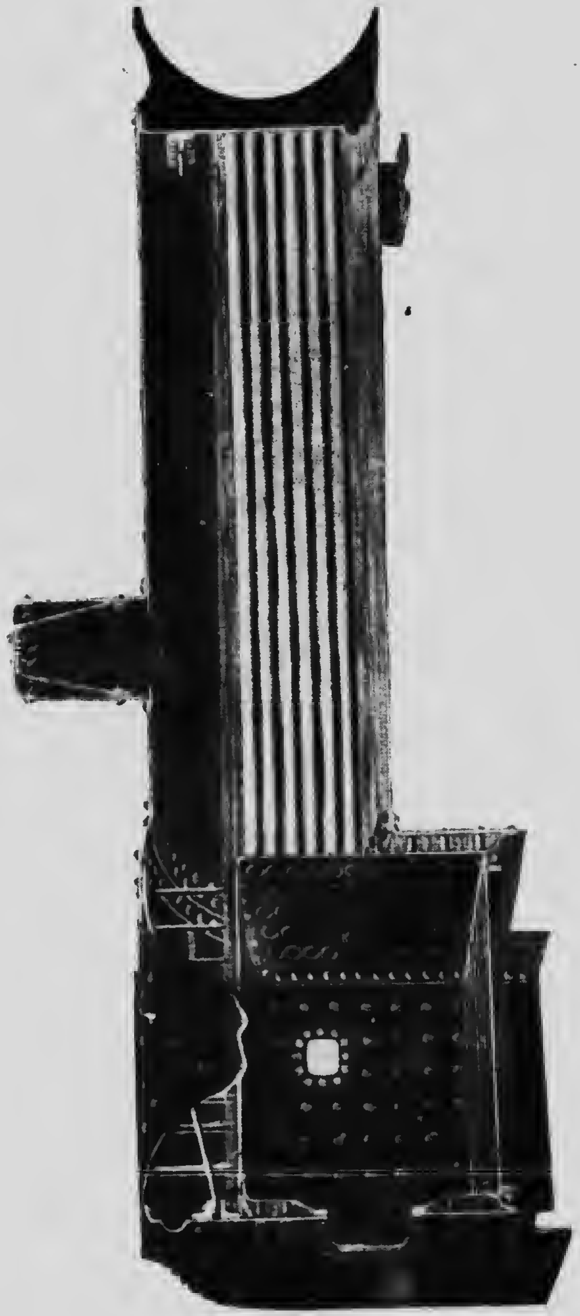


Fig. 11.

Fire Box Boiler. Figure 11 shows a fire box boiler fitted for burning coal or wood. This same boiler may be fitted for burning straw by putting in a fire brick arch and short grate with a dead plate in place of the regular wood or coal grates. The fire door would also be fitted with a chute to aid in feeding the straw. The small door at the left hand side of the fire box is for cleaning out the ashes that might accummulate behind the arch. This cut shows the full open-bottom fire box. An open-bottom fire box is convenient when it is necessary to repair or put in new tubes. A boiler of this type is necessarily longer than a boiler of the return flue type, in order to give the necessary distance of travel for the heat before it leaves the boiler.

Size of Boilers, Horse Power. In speaking of the size of a boiler it is common practice to state the size in horse power. The horse power, meaning the size of a boiler, large enough to furnish steam to an engine doing work equal to a given number of horses. There are two common methods of estimating the horse power of a boiler, one of which is to measure the amount of heating surface upon the boiler, the other is to measure the amount of water which the boiler will turn into steam in a given length of time, such as one hour.

Horse Power by Test. The American Society of Mechanical Engineers recommended, and it is now generally accepted, that the commercial horse power of a steam boiler be taken as an evaporation of 30 pounds of water per hour from feed water at a temperature of 100 degrees F. into steam at 70 pounds gage pressure, with good fuel and ordinary firing. In this way a 20 horse power boiler would use 20x30 or 600 pounds of water in one hour, doing 20 horse power work, providing the water was put into the boiler at a temperature of 100 degrees and the steam was used at 70 pounds gage pressure. If temperature or pressure vary from these figures, allowance should be made for it. In testing a boiler by this method the water would be carried at a certain height in the boiler, and the amount of water weighed or measured as it was pumped in when the boiler was in operation.

Horse Power by Heating Surface. It is quite common practice to estimate the size of a boiler by measuring the heating surface, and for ordinary boilers allowing about 14 sq. ft. of heating surface for each horse power. The heating surface of a boiler is all the surface that has water on one side of the metal, and fire or heat on the other. In a horizontal return tubular boiler, it would be all the surface contained in the lower half of the shell, the tubes, and the tube sheets. On the horizontai boiler the brick work strikes the side of the boiler about half the way up, and for this reason we figure the lower half of the shell.

For example, suppose we had a boiler 36 inches in diameter, 10 feet long, with thirty 3-inch tubes, and wished to know the amount of heating surface and horse power. One half of the circumference equals 4.71 feet; 4.71 times 10 feet equals 47.1 square feet in the shell. The circumference of each tube is 9.42 inches; the length of each tube 120 inches; 9.42 times 120 equals 1,130.4 square inches; 1,130.4 square inches divided by 144 equals 7.85 square feet heating surface in one tube; 7.85 times 30 equals 235.5 square feet in 30 tubes. For the tube sheets we would measure the surface of both sheets and deduct the area of the tubes, also deduct the suface above the water. The heating surface of the sheets in this boiler would be about 7 feet. Adding the heating surface,—47.1 feet in the shell, 235.5 feet in the tubes, 7 feet in the tube sheets,—gives us 289.6 square feet of heating surface:

289.6 divided by 14, the number of feet required for one horse power, equals 20.6 horse power.

On some types of boilers it is customary to allow a little less than 14 square feet of heating surface for one hore power, and on some types a little more, depending somewhat upon how effective the heating surface is; 14 square feet is but a general average. In comparing the size of boilers, figuring the heating surface and considering how effective it is gives a very good comparison.

Horse Power by Grate Surface. Sometimes the horse power of a boiler is roughly estimated by the number of square feet of grate surface. This is found by multiplying the length of the grates by their width. The amount of grate surface required under a horizontal tube boiler for one horse power, would be from one-third to one-half square foot. If the grates of a boiler were 36x42 inches, it would give 10½ square feet. Allowing one-half square foot for one horse power, it would be sufficient grate surface for a 21 horse power boiler. Figuring the horse power of a boiler by grate surface is not nearly as accurate as figuring it by the heating surface.

Steam Domes. Steam domes on boilers are placed on top of the boiler for the purpose of increasing the capacity for the storage of steam, and to afford a ready means of drawing off the dry steam. They are desirable and necessary on traction engine boilers, especially when moving on the road and there is considerable agitation of the water from moving. On a stationary boiler a steam dome is not necessary, and in many cases no domes are put upon the boilers. Boilers having no domes generally have the tubes put in a trifle lower down, and thus secure the additional steam space in the boiler above the tubes. The dome is objectionable in that it weakens the boiler and, unless covered with non-conducting covering, is apt to condense the steam in the boiler to some extent.

BOILER FITTINGS.

Water Columns. The water column on a boiler consists of a hollow cylindrical casting about 3 to 4 inches in diameter by 12 to 18 inches in length, into which are screwed the

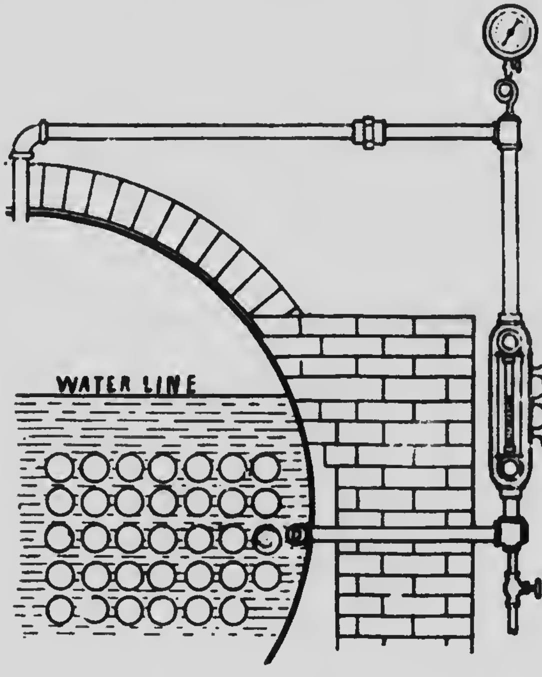


Fig. 12.

gage-cocks and glass gage. Often the steam gage is attached to the upper end, and a valve for blowing out, at the lower end. The lower end of the water column is connected to the boiler in the water space, and the upper end is connected to the top of the boiler or steam space, as shown in Figure 12 which shows the manner in which they are generally placed on boilers set in brick work.

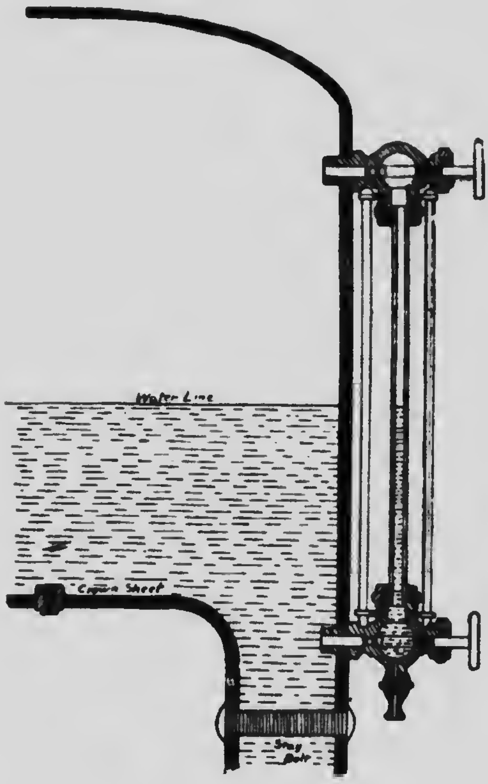


Fig. 13.

The purpose of the water column is to show the amount of water in the boiler. If it is kept clean on the inside and the valves open, the water will stand at the same height in the water column as it does in the boiler, and will show this height in the glass and at the gage-cocks, as water will always find its own level if the pressure be equal on each side.

It should be so placed on the boiler that the bottom of the glass gage will be level with the

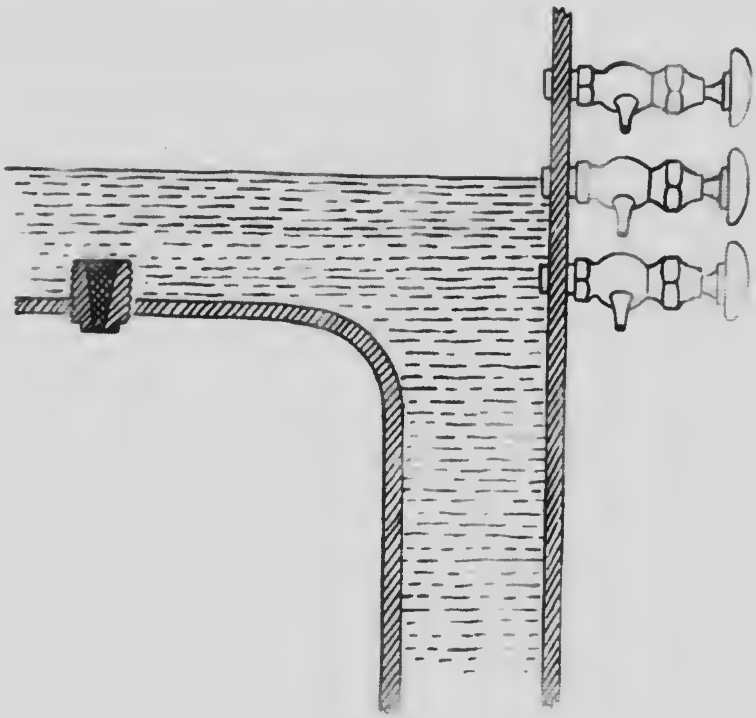


Fig. [illegible]

top of the upper tubes in the horizontal tubular boiler, or level with the top of the crown sheet in the fire box boiler. It can then be seen by looking at the glass just how high the water is over the tubes or crown sheet. The lower gage-cock should be about one inch above the top of the upper row of tubes in the horizontal return tubular boiler, or the crown sheet in the fire box boiler. The middle gage-cock should be placed about 4 inches above the upper tubes or crown sheet, and the upper gage-cock about 7 inches above the tubes or crown sheet.

On some boilers, especially the fire box, no water column is used, the glass gage being screwed directly on to the boiler, as in Figure 13.

The gage-cocks in this case are also screwed directly on to the boiler, as in Figure 14.

Height of Water to Carry. When a water column is properly set the water should be carried near the middle gage-cock, which would give about 4 inches of water over the tubes or crown sheet in an ordinary boiler. A large boiler would carry a little more water, and would generally have a larger water column with gages farther apart. On a small boiler the water would perhaps be a little lower. If there was danger of foaming or priming with the boiler, the water might be carried down to about 2 inches over the tubes. If too much water is carried it does not allow enough steam space in the boiler, or room for the water and steam to separate, and the water is carried over with the steam into the engine. A boiler may be priming a little, but not enough to call the engineer's attention to it. This is wasteful of fuel and water, as cold water must be pumped into the boiler to replace the hot water that is passing out with the steam. Carrying too little water in the boiler is liable to cause trouble from burning the tubes. If an engineer carries low water, say 2 inches over the tubes, and if something should happen to the pump or injector so they stopped feeding, the water would soon become dangerously low. When carrying low water an engineer must be very watchful of the pump or injector.

Leveling Water Column. On taking charge of a steam boiler an engineer should always level his water column so as to know just how it is set. They are frequently put on by careless workmen too high or too low. If placed too high and the water is carried near the middle gage-cock, there will be more water than necessary over the tubes or crown sheet, and the boiler will be very liable to prime. If put too low and the water is carried near the middle gage-cock, there will not be enough water over the tubes or crown sheet to keep them covered the proper depth

There is danger of burning the tubes or causing them to leak, and danger of melting out the safety plug.

The water column may be leveled by using a common spirit level and leveling from the top of the tubes around to the glass. Or when filling the boiler with water fill it until the water just shows in the glass, and then look in the top manhole or hand-hole and see if it covers the tubes. If not, fill boiler until it just covers the tubes, and then note just how much there is in the glass. It would be well to put a mark upon the water column that is just at the level of the top of the tubes, for a guide as to just how much water there is over the tubes. If the water column is too high or too low, it is not always advisable to change it, but the engineer should find just how it is set and then carry the proper amount of water. It is the amount of water over the tubes or crown sheet that makes a boiler safe and economical in the use of water and fuel, not the amount of water in the water column.

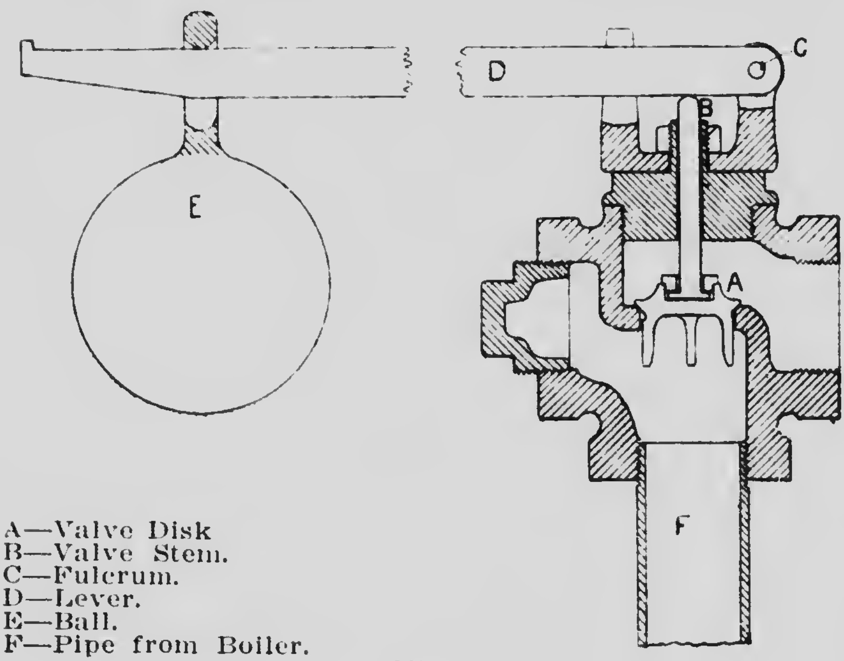
Cleaning the Water Column. There should be a cross put on below the water column where the pipe comes out from the boiler, and the lower opening should be connected with a valve for blowing out. This valve should be opened often and the water blown out a little so as to clean the pipe between the boiler and the lower end of the water column. This pipe, if not blown out, is liable to become filled with mud or scale. The side of the cross should be closed with a plug and the pipe scraped occasionally to keep it free from scale. It often happens that this pipe closes up. In this case the water column of course would not show the proper amount of water.

Breaking Glass Gage. There are valves at the top and bottom of the glass gage, which must be kept open when running. When shutting down in cold weather when there is danger of freezing, they should be closed at night and the glass drained. It is also advisable to close them when the boiler is left for any length of time. These valves should be examined occasionally, and especially in the morning, to make sure they are wide open. In case the glass gage breaks while running, the valves should be closed to prevent the escape of water and steam. The height of the water can then be told by the gage cocks until a new glass is put in. New glass gages should always be kept on hand, as they are liable to break at any time. Rubber gaskets for the glass should also be kept on hand, as the old ones are liable to be too hard to use again and it is difficult to get fibrous packing in tight. If a new glass is too long, it may be cut by breaking off the tip of a three-cornered file so as to get a sharp corner, and scratching the glass on the inside, where you wish to break it. It will then break easily.

Safety Valves. A safety valve is absolutely essential to every steam boiler in order to relieve the pressure when it reaches a certain limit, and thus avoid danger from explosions. It should open when the pressure reaches a fixed limit, and be large enough so that no increase of pressure can then occur. It should be connected directly to the boiler with no valves between it and the boiler, and there should be no other steam taken from the same opening. Safety valves are of two kinds, the ball and lever and the pop or spring safety valve.

Ball and Lever Safety Valves. A cross section of the ball and lever safety valve is shown in Figure 15.

Ball and lever safety valves are often used on stationary boilers, and while not quite so reliable as the pop safety valve, they are a little cheaper and answer the purpose fairly well. The pressure at which the ball and lever safety valve will open is regulated by the ball E. Moving the ball towards the safety valve will allow it to blow at a lower pressure; moving it out towards the end of the lever will allow it to blow at a higher pressure. The pressure at which a ball and lever safety valve will blow off can be figured by knowing the



A—Valve Disk
B—Valve Stem.
C—Fulcrum.
D—Lever.
E—Ball.
F—Pipe from Boiler.

Fig. 15.

area of the valve disk A, the weight of the valve disk and stem, the weight of the lever, the weight of the ball, the distance from where the valve stem touches the lever to the fulcrum C, and the distance from the ball to the fulcrum C. This rule in practice, however, is not often used. The safety valve being set by the steam gage when the valve and gage are both new and in good condition, the ball will then be placed at the proper place on the lever to blow off at the desired pressure. The lever should be marked at this point distinctly in order that the engineer may tell at a glance whether the ball has been moved or not. If the ball has not been moved, the valve should always blow at the same pressure, unless the valve disk A is stuck in its seat. It sometimes rusts in its seat and will not open at the proper pressure. A safety valve should be opened every morning after about 10 to 40 pounds steam pressure has been raised, in order to be sure that it is not stuck and is in good condition. The position of the ball on the lever should be noted at the same time.

A safety valve should not be opened when the steam gage registers more than five pounds above the blowing off point as the indication would be that the valve was stuck in its seat and opening it would relieve the pressure too quickly. It would be best to check the fire, start the pump or injector and when the pressure is one or two pounds above the blowing off point open the safety valve.

Rules for Figuring Ball and Lever Safety Valves. The following rules are given in order that an engineer may be able to figure the proper blowing-off point of a safety valve. In each of the three rules the same size valve, lever, etc., are used. The dimensions are as follows:

Weight of ball 25½ pounds.

Required pressure—100 pounds per square inch.

Distance from fulcrum to valve stem—2 inches.

Weight of lever, valve and valve stem, (taken directly above the valve stem by means of a spring scale)—8 pounds.

Diameter of safety valve—2 inches.

Area of safety valve (2x2x.7854) equals 3.1416 square inches.

Rule 1. To find distance ball should be placed on a lever, multiply the pressure required by the area of the valve. Subtract the weight of the lever, valve and stem, and multiply the answer by the distance from fulcrum to center of valve stem. Divide by the weight of the ball, and the answer will give the distance to place the ball from the fulcrum.

Example:

Pressure (100 pounds) multiplied by area of valve (3.1416) equals 314.16.

314.16 less weight of lever, valve and stem (8 pounds) equals 306.16.

306.16 multiplied by distance from fulcrum to center of valve stem (2 inches) equals 612.32.

612.32 divided by weight of ball (25½ pounds) equals 24 inches, length of lever, answer.

Rule 2. To find weight required for a given pressure, multiply the pressure by the area of the valve. Subtract the weight of the lever, valve and valve stem, and multiply the answer by the distance from fulcrum to center of valve stem. Divide by the length of the lever from the fulcrum to the point of bearing of the ball upon the lever.

Example:

Pressure (100 pounds) multiplied by area of valve (3.1416) equals 314.16 square inches.

314.16 less weight of lever, valve and stem (8 pounds) equals 306.16.

306.16 multiplied by distance from fulcrum to center of valve stem (2 inches) equals 612.32.

612.32 divided by length of lever (24 inches) equals 25½ pounds, weight of ball, answer.

Rule 3. To find the pressure, divide the length of lever by the distance from fulcrum to center of valve stem. Multiply answer by weight of ball. Add weight of lever, valve and stem, and divide by area of valve. The answer will be the steam pressure per square inch.

Example:

Length of lever (24 inches) divided by the distance from fulcrum to center of valve stem (2 inches) equals 12.

12 multiplied by weight of ball (25½ pounds) equals 306.

306 plus weight of lever, valve and stem (8 pounds) equals 314.

314 divided area of valve (3.1416) equals 99.95 pounds. Practically 100 pounds steam pressure, answer.

Pop or Spring Safety Valves. Pop or spring safety valves are generally used on the best class of stationary boilers, and are used on locomotives and traction engine boilers. They are a little more reliable than the ball and lever, and are not so liable to leak. They are so constructed that when they blow off steam the pressure will be lowered from one to five pounds, according to the adjustment of the valve. In closing they close quickly and are more likely to shut down tight than the ball and lever valve, which opens gradually. Figure 16 is a section of the Crosby pop safety valve.

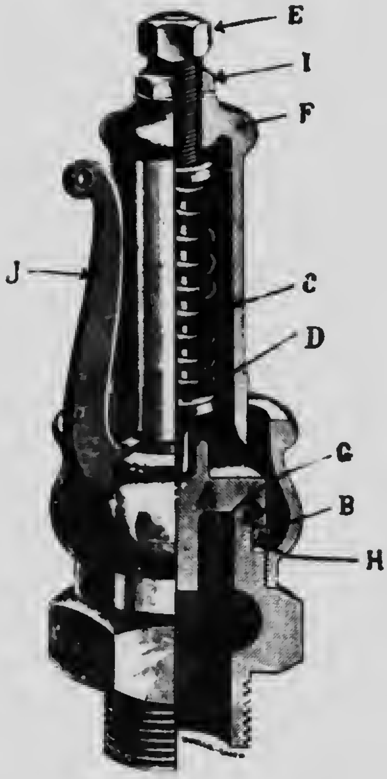


Fig. 16.

The valve disk A is held to its seat B by the spring C pushing on a spindle D. The pressure on the spring is regulated by the nut E which screws into the case F. The valve disk A has a groove G around its outside rim. As the valve rises it compresses the spring which increases its resistance, and without some provision it would be raised for only a short distance above the seat after steam commences to blow off. For this reason the top of the valve A is made considerably larger in diameter than the opening at B. In the under side of the valve the groove G is turned. When the valve lifts, this groove is filled with steam which pushes against that portion of the valve outside of the opening B, which causes the valve to rise higher and remain open longer than it would without this device. A ring H is screwed to the outside of the seat B. This can be screwed up or down and in this way the amount the valve will lower the pressure before closing may be regulated. The safety valve may be opened to blow off the pressure, by pulling the lever J.

In changing a spring safety valve to blow at a higher pressure, great care should be taken not to screw it down too tight, as there is danger of pushing the spring together and making it solid, which would not allow the valve to open enough to relieve the pressure.

A spring safety valve is set to required pressure by testing it with a steam gage.

Adjusting Pop Safety Valves. To increase the pressure at which the safety valve will blow off, loosen the lock nut I and turn the regulating nut E down, which will increase the tension of the spring C.

To decrease the pressure at which the safety valve will blow off, loosen the lock nut I and turn the regulating nut E up, which will decrease the tension of the spring C.

When the spring has been adjusted to the required pressure, turn the lock nut I down tight against the body of the valve F, to keep the regulating nut E from changing its position.

Setting Safety Valves. Safety valves should be set by the boiler inspector so as to blow off at the required pressure. An engineer should not change a safety valve after it has been set by the inspector.

Size of Safety Valve. The size of the safety valve depends somewhat on the pressure to be carried and the size of the boiler. For ordinary use it is customary, where the ball and lever safety valve is usd, to allow ½ square inch area of safety valve for each square foot of grate surface. In pop safety valves it is customary to allow ⅓ square inch area for each square foot of grate surface.

A larger safety valve is required on a boiler carrying a low steam pressure than on one carrying a high steam pressure, on account of the steam escaping faster through the valve at the higher pressure.

Fusible or Safety Plug. A fusible or safety plug, Figure 17, is put in a boiler as a safeguard against low water. It consists usually of a brass plug about one inch in diameter, having a taper hole about a quarter of an inch in diameter bored through its center. This hole is filled with a soft metal which melts at a low temperature. It should be filled with pure Banca tin, which is a metal something like lead, and melts at the proper temperature.

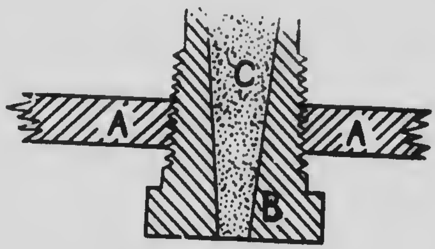


Fig. 17.

Sometimes when they melt out and no tin is at hand to fill them, they are refilled with solder or lead. In the fire box boiler it is placed in the crown sheet directly over the fire, as shown in D Figure 3. In case of low water the tin in the plug will melt out and let the steam escape into the fire box, putting out the fire and preventing the crown sheet from being overheated. The plug must then be removed and refilled. In the horizontal return tubular boiler it should be put at the back end just at the top of the upper row of tubes.

Occasionally a safety plug will melt out while there is water over it. This is liable to occur if the boiler is dirty, and the mud or scale forms over the upper end of the plug and prevents the water from getting to it to keep it cool. The safety plug should be screwed well into the boiler to be sure the upper end reaches entirely through the sheet.

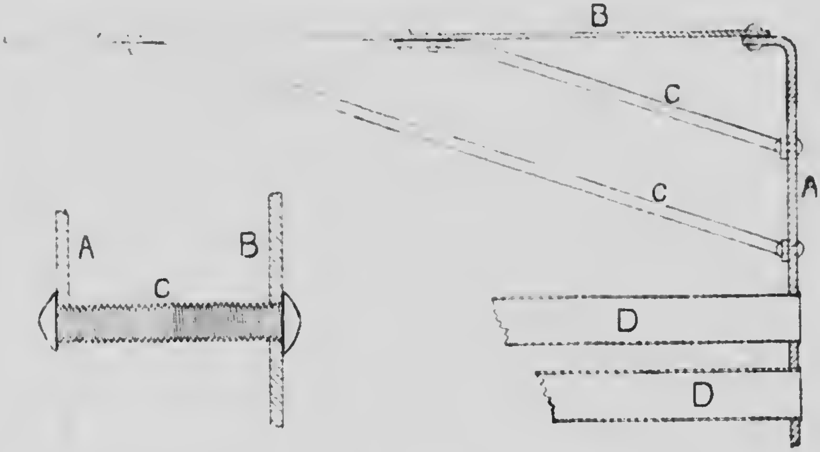


Fig. 8.

A—Fire Box Sheet
B—Outside Sheet.
C—Stay Bolt.

A—Tube Sheet.
B—Boiler Shell.
C—Braces.
D—Tubes.

Braces and Stay Bolts. Braces or stay bolts must be put in boilers wherever there are any flat places, in order to prevent bulging from the steam pressure. In a horizontal boiler braces are required above the tubes at each end. One end of each brace is riveted to the tube sheet and one end to the shell, as shown in Figure 18.

The tubes act as braces for the lower part of the boiler extending from one tube sheet to the other. Below the tubes there are often long braces extending from one end of the boiler to the other, which are known as "through braces." Stay bolts are put in fire box boilers between the fire box sheet and the outside sheet of the boiler in order to keep the sheets in position. They are usually put about four or five inches apart in each direction. They consist of a rod from ¾ to 1 inch in diameter with a thread cut the entire length. The sheets are drilled and threaded and the bolts screwed in from one side. The ends are then riveted down, which gives them the appearance of rivets. They should be tested occasionally to make sure they are not broken. This is usually done by holding a heavy hammer on one end and striking the other end with another hammer. If it sounds solid and does not spring, it is all right. If not it should be removed and another stay bolt put in.

Boiler Tubes. Boiler tubes are often called boiler flues. Strictly speaking a boiler flue is large and the heat passes through it in a body, as the main flue in the return flue boiler shown in Fig. 6, also the fire box return flue boiler shown in Figures 8 and 9. The tubes are generally smaller and larger in number, and the heat is divided in passing through them. Boiler tubes are made of a soft, tough iron or steel, something like iron pipe but thinner and softer. They are fastened in the tube sheet

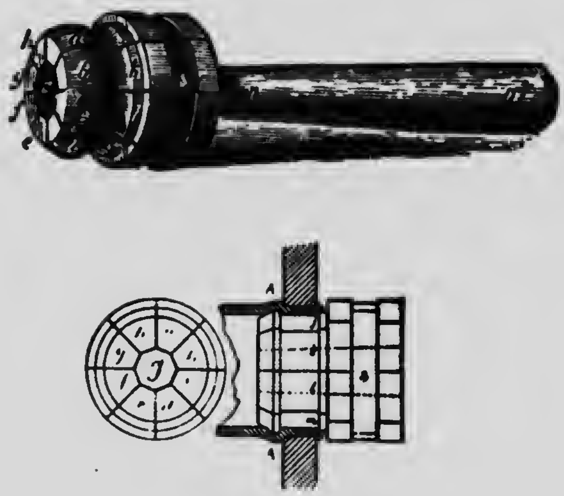


Fig. 19.

by expanding after being put in place with a tube expander. Two kinds of tube expanders are in common use, one is shown in Figure 19, called Prosser's Sectional Expander. The upper cut shows the expander, the lower cut its position in the tube. This expander raises a shoulder on the inside of the tube. In use the taper pin is driven in tight, which spreads the sections and enlarges the tube. The pin is then jarred out, the expander turned a little and then driven up again until tight.

A roller expander, Figure 20, is generally used for repair work and repairing leaking tubes. In using this expander the taper pin is driven in tight which spreads the rollers. The taper pin is then turned with a bar and in rolling rolls the tube out tight. Great care must be taken in expanding tubes to have them clean and free from scale or dirt Also

Fig. 20.

be careful not to expand them too much, which is liable to stretch the metal of the tube sheet and cause other tubes to leak.

After tubes are expanded they are beaded or turned down on the end, with a tool called a calking or beading tool, as is shown in Figure 21.

The long part of the beading tool enters the tube, the round part fits the bead or end of the tube where it turns up against the sheet. Leaking boiler tubes can almost always be stopped with the beading tool. In case they cannot be stopped with the beading tool, use the expander and then bead them.

Cleaning Tubes. Tubes should be kept clean in order to give proper draft to the furnace, and in order that the fuel may be used economically. They should be cleaned by the use of a scraper, or by using a steam tube blower which blows the soot out. If the latter is used, the scraper should also be used occasionally.

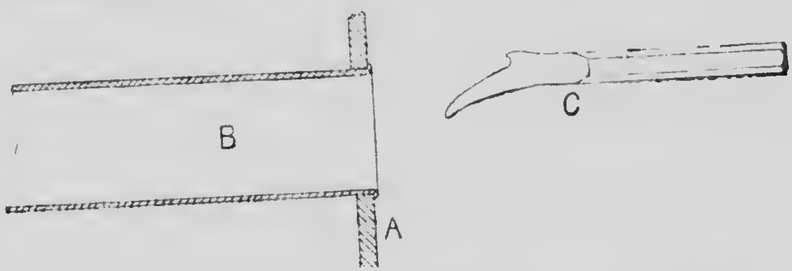


Fig. 21.

On a traction engine the tubes should be scraped in the morning before firing up while the boiler is cold. Do not attempt to clean the tubes just after starting the fire, as the tubes are then liable to be wet and sticky. If it is necessary to clean the tubes when there is fire under the boiler, or steam pressure on, they should be cleaned as quickly as possible, and care should be taken that cold air does not strike the tubes.

The Steam Gage. The steam gage is an instrument for showing the steam pressure in the boiler, the pressure being shown in pounds per square inch. When the gage shows 100 pounds, it means there is a pressure of 100 pounds against every square inch of the boiler

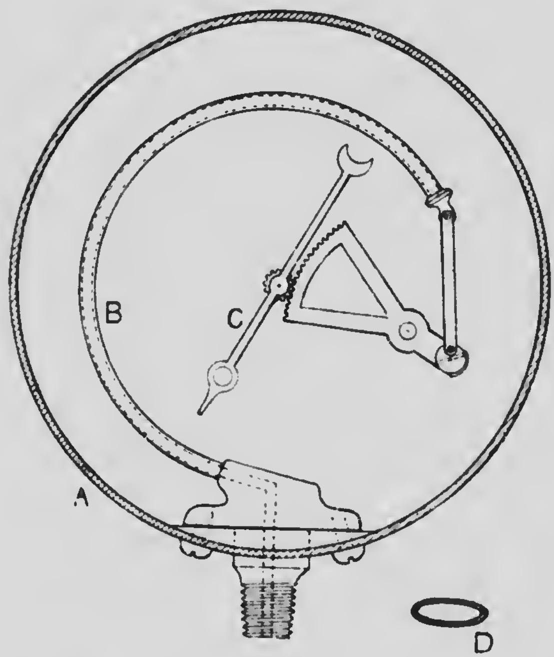


Fig. 22.

surface. Figure 22 shows the internal construction of a steam gage. For high pressure, steam gages are made with a double tube, which are better than the single tube gages.

It usually consists of an elliptical hollow tube bent in a circle. As the pressure in the tube increases it tends to straighten, and in straightening turns a small pinion which moves the hand or pointer. It is of delicate construction and should not be tampered with. It should always be connected to the boiler with a syphon, which usually consists of a small pipe with a bend or curl in it. The object of the syphon is to keep a "plug" or piston of water between the steam in the boiler and the air in the tube or spring of the gage. If the gage were connected directly with the boiler, steam would enter the tube and it would not register correctly, but by having the syphon, air, which is elastic, is kept in the tube. When steam is raised in the boiler some of it goes to the syphon, where it condenses and forms water which goes to the bottom of the coil or syphon. When the steam pressure increases it forces the water up the syphon, compresses the air in the tube and causes the tube to slightly straighten. In straightening it turns the hand or pointer of the steam gage.

Steam gage connections should always be tight. Any leakage between the steam gage and the boiler is liable to allow the air in the steam gage to escape, when it will not register correctly.

Threshing engines usually have a syphon consisting of a brass bulb, which answers the same purpose and is more rigid than the coil syphon.

A steam gage and syphon should not be allowed to freeze. If there is danger of their freezing, better wrap them with old cloths or sacks. A steam gage should be tested once a year at least by an inspector, to see if it registers correctly. If at any time there is any doubt as to its accuracy, it should be taken to where there is another boiler whose gage is known to be correct, and attached to the steam pipe or outlet, to see if it registers correctly. If not, it had better be sent to a competent machinist for repairs, or a new gage secured.

The safety valve and steam gage should correspond with each other. If the safety valve is set to blow at 100 pounds, and the steam gage registers 90 or 110 pounds when it blows off, it is evident that something is wrong with either the gage or the safety valve, and they should have immediate attention. The hand or pointer of the steam gage should always return to the pin or O when the steam is down, and it should start to rise as soon as pressure is observed at the gage-cocks.

Manholes and Handholes. Manholes and handholes are openings in boilers for the purpose of cleaning and examining them on the inside. The manhole is made large enough for a man to enter, or about 11x15 inches in size. The handhole is large enough for a hand, or about 3x5 inches in size. They are made elliptical in shape. The plate is held in place by a bolt passing through a yoke on the outside. They are made tight by using sheet packing called "gasket" which is generally made of rubber with cloth insertion. Gaskets for handholes should be one-sixteenth to one-eighth of an inch thick. For manholes it should be about one-quarter of an inch thick. Sometimes engineers make them out of old rubber belting. There are several kinds of patent gasket packing, some of which are very good. One kind, the Eclipse Tubular Gasket, is a round rubber tube nearly solid. It comes in pieces about 10 feet long. Gaskets are made from it by cutting off a piece just long enough to go around the manhole plate. A small lead dowel is put in the joint where the ends come together, the joint then being covered with a strip of tape which comes with it. When the plate is tightened up the gasket flattens out and fills all irregularities of the iron, making a tight joint. Gaskets should be thick enough to make a tight joint without using white lead, as the lead sticks to the gaskets and iron and is difficult to remove. By using a little graphite and oil on the gaskets, they may be removed easily and used several times. When a new gasket is put in, it is best to tighten it again after the boiler is warmed up, as in warming the gaskets usually soften.

CARE OF BOILERS.

Boiler Cleaning. To do good service and be safe, a boiler should be kept clean inside and out. The frequency of washing a boiler on the inside depends entirely upon the kind and amount of water used, and can best be told by observation. Usually a threshing boiler should be washed once a week. If the water is bad or dirty, it should be washed oftener. But if clear, soft water may be had, it can be run longer.

It has been decided by good authority that one-sixteenth of an inch of scale in the boiler will require 15 per cent more fuel. Scale in a boiler is a non-conductor of heat, somewhat similar to brick or earth. The heat from the fuel is not conducted through the scale to the water so readily as when the boiler is clean. Consequently, if a boiler is scaled, the fire will have to be forced harder and the boiler tubes and sheets will have to be heated hotter in order to get the required heat through the scale into the water. Considerable dirt may be removed by blowing off occasionally through the lower blow-off valve. It is good practice to fill the boiler with water up to the third or top gage-cock at night, then in the morning after firing up, when from 5 to 40 pounds of steam pressure is raised, open the blow-off valve and blow down to the second gage-cock, or where the water is usually carried. If the water is very muddy or dirty, it is a good plan to blow out a little at noon also, blowing out after the boiler has stood a while without firing, which would be just before starting up for the afternoon work. When a boiler is in operation and has a good fire in the furnace, the circulation of the water in the boiler tends to mix the dirt more or less throughout the boiler, and blowing off at that time will not remove a great amount of dirt. At night or at noon, when the boiler is at rest and the firing checked, the circulation will stop and the dirt will settle to the bottom, and may be blown out at that time.

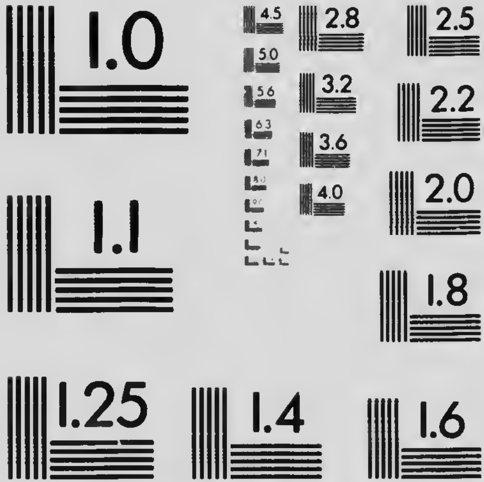
A boiler ought never to be blown out or emptied entirely while there is any steam pressure on, as it is liable to injure the boiler, and in time will cause the seams and tubes to leak. If a boiler is blown out entirely when steam pressure is on, the boiler of course is very hot, and being emptied quickly, the tubes being thinner than the shell, will cool much quicker, and on cooling will contract or shorten in length, while the shell cools and contracts or shortens more slowly. This causes a strain on the tube ends and is usually the cause of leaking tubes.

The best way to wash a boiler is to let it cool down until there is no steam pressure on it, or until the water is cool enough to bear the hand in. Then open the blow-off valve and let the water run out. Remove the hand-hole plates and scrape the tubes and boiler shell with a scraper made from a flat piece of iron with a rod for a handle. After scraping thoroughly, use a hose and wash it well. If you have no pressure on the water, a smal' hand force pump should be provided for the purpose. The boiler should be washed thoroughly.

Boiler Compounds. In some cases where the water forms a hard scale, it may be necessary to use a compound of some kind to prevent the scale from forming on the tubes and boiler shell. Whether a compound is necessary or not, and what kind of a compound to use, depends altogether upon the water. If the water is used from a pond or creek and is somewhat muddy, or has a substance in it that does not form a hard scale, no com-

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



pound can be used to any advantage. Blowing the mud out and washing the boiler is all that is necessary. Where the water has some substance in it that forms a hard scale, a compound may be used that will act upon the substance forming the scale so as to keep it soft in the form of mud, when it may be blown and washed out easily. Nothing can be put into water that will make it perfectly pure and free from substance that will form a mud.

Where a compound is necessary, the best way is to have the water analyzed by a chemist and have a compound made to fit the water, using just enough compound to act upon the scale-forming substance in the water. For a small threshing engine or creamery boiler it would hardly be practicable to make an analysis and have a compound made. On creamery boilers very good success has been had by using soda ash. It is comparatively cheap and gives off no offensive odor which would be objectionable where steam is used for heating milk or water used in a creamery. For an ordinary creamery boiler of 15 horse power, use about two pounds, putting it in after the boiler has been washed and before filling it with water. It will dissolve and work upon the scale and loosen it. After the boiler has been run two or three days, it should be opened and washed out again. After the scale has been removed, a small amount of soda ash would answer to keep the scale from forming.

Sal soda has also been used with good results in creamery and similar boilers. Use about the same as the soda ash.

For threshing boilers, and boilers where steam is not used for heating water or creamery purposes, kerosene has been largely used. It gives good results and is often recommended by inspectors and prominent engineers for removing scale already formed in boilers, also to prevent scale from forming. For threshing engines kerosene is probably as good as anything. It is best to feed it in through a feeder something like a sight feed lubricator, if this can be afforded, and feed a drop at a time into the feed water. When this cannot be afforded it is put in the boiler when the boiler is washed. After washing the boiler and before filling it with water, put in about one quart for each ten horse power of boiler. This will rise on the surface of the water when the boiler is being filled and coat the tubes and shell. Repeat this every time the boiler is washed.

Do not get the impression that you must

use a boiler compound in your boiler, and do not use a compound unless scale forms in your boiler. Blow out a little water every day, and wash the boiler often.

Foaming. When the water used in the boiler is dirty or impure, the steam and water do not seem to separate when the steam is given off, the water being carried over with the steam into the engine. When this occurs the boiler is said to be foaming. It may be told by the clicking of the water in the cylinder of the engine, the water rising and falling in the glass gage and the engine loosing speed or power, and by the water coming out with the exhaust steam. Foaming is nearly always caused by impure water, or a dirty boiler. When a boiler foams, the remedy is to open the cylinder cocks so as not to break out the cylinder head, and stop the engine for a moment which will let the water settle, and you may see how much water there is in the boiler. When a boiler foams, the water being mixed with the steam, is carried out of it quite rapidly, and the water will show higher in the glass gage than it really is in the boiler. If on stopping there is found to be water over the tubes or crown sheet, it will be safe to pump in more water. If the water, however, is below the crown sheet, it is best to stop and let it cool down a little before putting cold water in. If the boiler foams badly, it would be better to stop and pump in considerable water and then blow out some, so as to change the water and partly clean the boiler.

Often a sudden strain will be put on the engine, as going up a steep hill with a traction engine, or feeding the machine very heavy, and this is liable to start foaming. In such cases foaming may often be stopped by closing the throttle for an instant, and then starting again. A boiler is more liable to foam when high water is carried, than when the water is low. A boiler is also more liable to foam with low steam pressure than with high steam pressure. It would be advisable when bothered by foaming to carry a high steam pressure, and not to carry the water higher than necessary to be safe. A boiler that is liable to foam must be watched closely when carrying low water, and the engine stopped as soon as the foaming starts. If allowed to foam any length of time, the water will become dangerously low. If stopping for a few minutes, pumping in fresh water and blowing off will not stop foaming, the boiler had better be emptied, thoroughly cleaned and filled with fresh water. Sometimes a new boiler will foam on account of dirt and oil that gets into the boiler in being manufactured. A new boiler should be cleaned after it has been run a day or two.

Priming. Priming is very similar to foaming, the water being carried over to the engine in the same manner. It, however, is generally caused by carrying too much water in the boiler, or by the boiler not being properly constructed, there not being enough steam space in the boiler. It may also be caused by removing a large quantity of steam from the boiler very quickly, such as might be the case if the boiler was too small for the engine, or for the work required of it. Sometimes the engine piston is badly worn and leaks, or the slide valve may leak, or may not be properly set. In which case the engine would use more steam than the boiler was designed to furnish, and would be liable to cause priming. In case of priming, stop the engine to let the water settle. If the cause was from too much water, blow out some and then start the engine slowly. Carrying a high steam pressure and low water will aid in preventing priming.

Surface Blow-off Valve. Some boilers are provided with a surface blow-off, which consists of a valve placed in the boiler at the water line, or near the top of the water, the object being to blow off the scum or dirt that rises to the top. They should be placed on boilers that are liable to use dirty water.

Boiler Feed Pipe. The boiler feed pipe is the pipe between the pump or injector and the boiler, through which the water is forced into the boiler. There is some difference of opinion as to where it should enter the boiler. On horizontal tubular boilers it often enters at the front end, just above the tubes, and is continued on the inside of the boiler nearly to the back end. In this case the feed water is often heated to nearly the temperature of the water in the boiler before it strikes the tubes or shell. Quite often it enters the bottom of the boiler through the blow-off pipe. In this case it conduces to keep the blow-off pipe clean and prevent the scale from settling in it. On a threshing boiler it usually enters at the side of the boiler. There should always be a hand-valve, or valve that may be closed by hand, close to the boiler where the pipe enters, and a check valve in the feed pipe near the hand-valve. The hand-valve is placed close to the boiler in order to shut the water off in cold weather when there is danger of freezing.

Also that it may be closed in case the check-valve does not shut tight; or if some sticks, etc., get into the check-valve, the hand-valve may be shut to hold the water in the boiler while the check-valve is opened and examined.

Scale in Feed Pipe. The feed pipe should be examined on the inside occasionally to see that it is not scaled up. In some localities where the water is bad, it is often filled by scale forming on the inside. The scale is liable to be formed close to the boiler where the

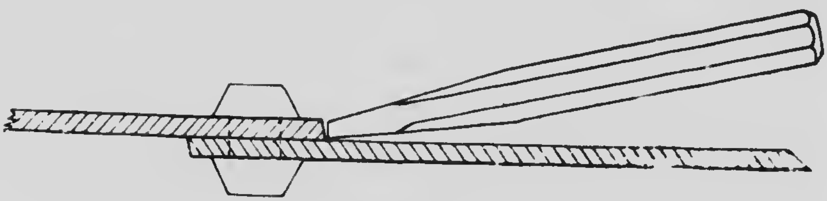


Fig. 23.

water enters, and often interferes with the working of the pump or injector. If the pump or injector bothers, and appears to be all right otherwise, the pipe should be examined to make sure it is not scaled up.

Leaks. Rivets and seams of boilers should be closely watched for leaks, and as soon as leaks are discovered they should be stopped, or they will get worse. They are usually stopped with a tool called a calking tool, which somewhat resembles a cold chisel, except that it is blunt on the end instead of being sharp. The tool is driven with a hammer.

Figure 23 shows the shape and manner of holding it in calking a seam. The object of calking is to rivet or upset the edge of a sheet until it is made tight. Care must be taken not to cut a groove in the sheet with a corner of the tool, as that would weaken the boiler. Some tools are made slightly rounding on the corners so as to prevent cutting a groove. A boiler should not be calked under pressure as it is liable to start a leak in some other place. The head of a rivet or stay bolt may be calked in the same way. Occasionally a pipe fitting is calked when it is impossible to screw it up tight. In calking a pipe fitting it is best to put in some packing before calking it. The [illegible] will then drive in some of the packing, and turn the metal of the fitting in so as to hold it. It is always best to screw up the pipe if possible, instead of calking it.

Boiler Troubles. Steam boilers should be constantly watched for defects that would weaken them or cause danger of explosion. In case they are found, they should be immediately remedied. A few of the common troubles are here given.

Blister. A blister in a boiler is where the metal of the shell separates. The shell would quite likely be straight on one side, and the other side would have a raised appearance similar to a blister. This is sometimes caused from poor material in the boiler, and often caused by not keeping the boiler clean. When the boiler is not kept clean the boiler shell is overheated and is liable to blister. When a blister occurs, the piece should be cut out and a patch riveted over the place. It would be better to cut out or remove a good sized part near the blister. If it is on a horizontal boiler, and the blister is on the lower part over the fire, the lower half of the sheet should be cut out and a new lower half put in, in order that no riveted seams would come directly over the fire.

Bag or Sag. A boiler is liable to bag or sag when it is dirty, or if a quantity of oil should happen to get into the boiler. It would be liable to stick to the lower sheet and prevent the water from getting down to the sheet and keeping it cool. In this case the sheet becomes overheated When it becomes overheated it weakens, and the pressure in the boiler would stretch it and push it outward, causing the bag. When the bag is formed the stretching of the sheet allows the scale or dirt over the bag to break, the water then gets through to the sheet and cools it and prevents it blowing out entirely. A boiler should not be run after it is bagged, as the bag will soon fill up with dirt or mud and soon be overheated, when there would be danger of an explosion. If a boiler is bagged only a trifle, sometimes it is "set back" by emptying the boiler and putting a furnace underneath it, heating the bag red hot and hammering it back into place with a hammer. If the bag is very large, it had better be cut out and a new half sheet put in.

Cracks. A crack on the shell of a boiler is rather difficult to find, especially when a boiler is covered with brick-work or covering. A boiler that has a crack along any of the seams should not be used. Occasionally a crack will appear on a boiler in the tube sheets, between the tubes. Often they are caused by expanding the tubes too much. A crack of this kind is not necessarily dangerous, the main trouble being caused from the leakage. They are often stopped by drilling a small hole at the end of the crack and putting in a rivet, which will prevent the crack from extending further. The crack is then turned down with a hammer or set down with a calking tool, so as to prevent leakage.

Pitting. Pitting in a steam boiler is generally caused from something in the water, or something in the material of the boiler shell. When a boiler is pitted it has the appearance of small holes in it about one-sixteenth of an inch deep, or deeper, depending upon the amount of damage that has been done. If a boiler is pitting, it is advisable to change the supply of water and obtain it from another source.

Rust or Corrosion. A boiler is apt to rust or corrode when it is allowed to become wet and then dry, the rust eating the iron. It is sometimes caused by a hand-hole leaking a little, or water dropping from a leaking joint on to some part of the boiler. The leak should be stopped and the boiler made perfectly tight. When a boiler is laid up for some length of time and is not being used, it is liable to rust. In cases of this kind, the outside of a boiler should be painted with black asphaltum paint or graphite and oil paint, when it is put out of service. If the boiler can be emptied and dried thoroughly on the inside, and connections opened so no water will be allowed to leak into it, it is best to leave it empty and dry. If it cannot be left dry, it is a better plan to fill it entirely with water unless there is danger of freezing. When a boiler is filled with water the water prevents to some extent the air from acting upon the iron and rusting it.

Laying Up a Threshing Boiler. In laying up a threshing boiler in the f . when the season's work is over, it should b thoroughly washed and scraped on the inside, and the blow-off valve left open. The outside of the boiler should be scraped free from dirt and grease, and all iron work of the boiler given a coat of black asphaltum paint or graphite and oil paint. Many engineers make the mistake of painting their engines in the fall just before starting the season's threshing. It is much better to paint them when the season's work is over. The paint will then protect them while laid up and also thro h the threshing season. The boiler should e kept under cover during the winter.

FIRING.

Firing. Before starting fire under a boiler always make sure it contains sufficient water by examining the gage-cocks and glass gage. Do not depend upon simply looking at the glass gage, but examine it by trying the valve at the top and bottom of the glass, to clean the glass, and see if the water rises quickly to the same level again. Also try the gage-cocks and see that they and the glass gage show the same amount of water. See that the tubes and grates are clean before starting the fire.

Combustion. The term combustion, in ordinary use, means the union of a substance with oxygen. As it takes place in the air, light and heat are always produced. The oxygen necessary for combustion is taken from the air, and the substance to unite with it is supplied in the fuel. All substances used as fuel contain carbon, hydrogen, and a small amount of mineral matter. The carbon and hydrogen unite readily with oxygen, but the mineral matter remains in the form of ash. When plenty of air is present, the carbon unites with the oxygen and forms carbon dioxide. If sufficient air is not present to supply the oxygen, the carbon and oxygen form carbon monoxide. The hydrogen and oxygen form steam or water.

Igniting Temperature. Substances do not usually combine with oxygen at ordinary temperature, but in order to effect the union, the temperature must be raised. Some substances need to be heated to a much higher temperature than others before they will combine with oxygen. The temperature at which a substance unites with oxygen and produces heat and light, is called its kindling temperature or igniting temperature.

Heat of Combustion. It is the chemical union of the substances that produces heat. The amount of heat is usually given in British Thermal Units (B. T. U.), which is the amount of heat required to raise the temperature of a pound of water from 62 to 63 degrees Fahrenheit. By experiment it has been found that one pound of carbon burned to carbon dioxide produces 14,500 B. T. U.. When burned to carbon monoxide, 4,400 B. T. U. are produced. When one pound of hydrogen combines with oxygen, it liberates 62,000 B. T. U.

Economical Combustion. It is not possible in practice to obtain perfect chemical combustion, because of the variations of the air supply, and the difficulty of bringing the air in contact with all parts of the fire. If too much air is admitted to the furnace, the extra amount will carry heat up the chimney. If too little air is admitted, the carbon will combine with the oxygen to form carbon monoxide instead of carbon dioxide. The higher the temperature at which the fuel is fed to the fire, the more perfect will be the combustion, and therefore the fuel will be used more economically.

A fireman, therefore, should be careful to see that neither too much nor too little air is supplied to the furnace, and should so manage his furnace as to burn the fuel at as high a temperature as possible.

Temperature of Combustion. The temperature of combustion varies with the kind of fuel used. If no allowance for loss of heat is made, and the proper amount of air furnished, burning carbon should have a temperature of about 4,940 degress above zero. Burning hydrogen should have a temperature of about 5,800 degrees above zero. In practice these temperatures are not attained on account of the loss of heat. The quantity of air admitted to the furnace is generally about double the amount that is theoretically necessary. This extra air enters at a temperature of from 40 to 90 degrees, and escapes up the chimney at a temperature of from 400 to 600 degrees. When this takes place a considerable amount of heat is wasted, and the temperature of the fire is lowered.

Where a boiler is set in brick work, the furnace temperature under ordinary conditions will generally range from 2,000 to 3,000 degrees. In a fire box boiler, where the fire is surrounded by water, the temperature seldom rises above 2,000 degrees. A high temperature is desirable, as the water in the boiler will take up the heat faster at a high temperature and the combustion of the fuel will be more perfect.

Smoke Prevention. In order to prevent black smoke, the fuel should be burned at a high temperature and should be added to the furnace in small quantities. The door should be opened and closed quickly. Black smoke is generally caused by putting in considerable coal at a time and leaving the door open longer than is necessary. When this occurs, the fuel added being cold, and the cold air entering through the doors, the temperature of the furnace is lowered considerably, and the temperature is not high enough to burn the gas and fine particles of carbon which are given off as smoke. When the fuel is burned in the furnace at a high temperature, the fine particles of carbon and gases which produce the smoke, are burned before passing out. By firing in small quantities and closing the door quickly, the heat will not be reduced below a temperature sufficient to burn them.

Firing with Soft or Bituminous Coal. In firing with soft coal, start the fire with shavings or old paper first, then put on kindling wood. When it is burning nicely, put on coal. Soft coal should be broken into pieces about the size of a man's fist. Do not put it on in chunks. Keep the fire even and put on fresh coal regularly, a little at a time. Put the coal on quickly, tipping the shovel so as to spread the coal evenly over the fire, and close the door as soon as possible. Do not allow any dead or burned out places to exist in the furnace. As soon as the coal burns down, put on more fresh coal, so as to keep the grates covered with burning coal and not allow any cold air to get through the fire, as cold air will cool the furnace and waste fuel. In case the boiler fires very easily or is not working hard, do not regulate the fire by letting it die out in places. Better keep an even fire over the grates and regulate it by closing the draft door and damper. When the boiler is large for the amount of work done and does not require heavy firing, it is often more economical to cover over the back part of the grates with brick, building it up the same as the bridge wall, bringing the bridge wall ahead on to the grates, so as to shorten the grates and make less grate surface under the boiler. The fire can then be allowed to burn more freely, the draft and damper be left open more which will burn the fuel at a higher temperature, and which will be more economical than keeping the draft and damper closed and burning the fuel at a lower temperature.

Different furnaces and fuels require different thicknesses of coal beds for economical firing. The proper thickness can only be found by trying the furnace. With a poor draft or fine coal the fire must be thinner than where the draft is good and the coal is coarse. The thickness will vary from three to eight inches. A furnace may be forced more when the coal bed is kept thin and clean.

Some engineers believe they can get better results by coking the coal. This is done by putting the fresh coal on in the front of the furnace and allowing it to remain until it is time to put on more coal. It has then become heated and has given off considerable gas and smoke. Then before putting on fresh coal, it is pushed back in the furnace with the hoe, and the fresh coal put on in front again. This is repeated every time coal is put on. The object of firing in this manner is to keep the fire in the back part of the furnace as hot as possible, and so burn the gas and smoke from the fresh coal as it passes over. There is probably less smoke given off when the firing is done in this manner, but it is doubtful if much fuel is saved on account of the fire-door having to be kept open when pushing back the coal, thereby letting cold air in to cool the furnace. It is generally considered the best practice to keep the fire level and spread the fresh coal evenly on the top, putting in the coal and closing the door as quickly as possible. It is best not to disturb a coal fire with poker oftener .than necessary When the coal is poor and forms clinkers, which are the coal and ashes melted together in a solid mass, the clinkers should be broken up and pulled out with a hook.

When steam starts to rise in a boiler, which may be seen by opening the gage-cock, the steam gage should be noticed to see if it is commencing to register, and when from 10 to

40 pounds of steam is on the boiler, the safety valve should be opened to make sure it is not stuck. If the boiler has just been cleaned, watch the handholes and see if the gaskets are tight, as they usually soften on becoming warmed up and should be tightened again.

Cleaning the Fire. When a coal fire has burned for several hours and considerable ashes and clinkers have formed, it must be cleaned. This consists in pushing the live coal to one side of the furnace and with the hoe raking out all of the ashes and clinkers from that side. Then push back part of the live coal and put on a fresh quantity. When this gets to burning nicely, clean the other side of the furnace in the same manner. Do not clean the fire oftener than necessary.

Banking the Fire. Banking the fire consists in covering it with fresh coal or ashes and closing the damper and draft. This is done to prevent the steam pressure from rising in case it becomes necessary to stop the engine and the fire is burning briskly in the furnace. Sometimes a fire is banked when it is desirable to keep it over night. When banking for this purpose it is best to push the fire back against the bridge-wall, rake out the clinkers and ashes, then put fresh coal on top and in front of the live coal, close the draft and leave the damper open over the fire enough to take off the gas and smoke. If the boiler has a strong draft, sometimes it is necessary to put ashes on top in order to hold it from burning through too quickly.

When it is desired to raise steam again, take the hoe and rake the coal ahead on to the grates, open the draft and damper, and it will burn up quickly. Where a boiler is used every day it is considerably more economical to bank the fire and hold it over night, than it is to allow the fire to go out and kindle fresh every morning.

Drawing the Fire. Drawing the fire consists in pulling the fire out of the furnace with the hoe. This is done in case the water gets dangerously low in the boiler, or it is desirable to have the boiler cool off as quickly as possible. A fire should not be drawn without being first covered with ashes or earth, or even fresh coal. If an attempt is made to draw the fire without first covering it, it will become very hot on being stirred up, and will not only heat the boiler still more, but will make it very hot in front of the boiler and difficult for the fireman to draw the fire out. Never put water in a furnace to put out the fire, as it is not only liable to crack the grates but will turn into steam and blow some of the fire out through the fire-doors.

Cleaning the Ash-Pit. The ash-pit should always be kept clean in order to give a free passage for air to the fire and prevent the grates from burning out. Grates are nearly always burned out by allowing the ash-pit to become full of ashes, and stopping the circulation of air. When the circulation of air is stopped the grates are practically in the fire and become overheated, and the heat and weight of coal warps them and burns them out. Grate bars should not fit tight in the furnace. There should be about ½ inch play at the ends and sides when they are put in so as to allow for expansion when they become heated.

Firing with Wood. Firing with wood is quite different from firing with coal. In firing with wood the firebox or furnace should be kept quite full. Keep putting in the wood as fast as it burns out, so as not to allow any open place for the cold air to enter through the fire. Do not disturb the fire more than is necessary. Fire quickly and keep the door closed as much as possible. To bank a wood fire, cover it with ashes and close the draft and damper.

Firing with Straw. In firing with straw, start the fire by putting a small amount of straw into the funnel of the door and lighting it; then push it in with another small forkful, keep putting in the straw regularly and in small forkfuls, being careful not to pack it or get in too much so as to stop the draft. A strawburning boiler cannot be forced by filling the fire box too full, there must be room for the air to get through it. The fire should be stirred frequently with the fork in order to break down the ashes formed from the burning straw. The ashes should be removed frequently and wet down with water to keep them from blowing about and causing fires.

Cleaning Tubes. The tubes or flues should be cleaned before starting the fire when the boiler is cold. As a rule do not allow more than one-sixteenth of an inch of soot in the tubes. Tubes should not be cleaned when there is a hot fire in the furnace, unless it is very necessary. In case it is necessary, clean them and close the door as quickly as possible, to prevent cooling and consequently leaking. The tubes of a threshing boiler should not be cleaned when the engine is running; neither should they be cleaned when steam is on, and there is a strong wind blowing which would strike them when the door is opened. Better to wait until the engine is moved if possible.

Some boilers are set in a small boiler room with a small door or window in front of them to be opened when cleaning the tubes in order to make room for the flue cleaner handle. This door or window ought not to be opened, as the cold air strikes the tubes. It would be better in such a case to have a hinge joint in the handle of the flue cleaner. This joint can easily be made by cutting the handle in two, flattening the ends, drilling a hole through them, and putting in a small rivet or bolt.

The Blower. In setting a stationary boiler the chimney can be built high enough to get a sufficiently strong natural draft without the use of a blower, but in a threshing engine it is not practicable to have a high chimney or smoke stack, and some other device must be provided in order to get sufficient draft. This is done when the engine is not running by using the blower, which is simply a small pipe running from the steam space in the boiler to the base of the smoke stack. The end of the pipe is reduced in size and shaped like a nozzle, and turned upward in the center of the stack. The steam is regulated by a valve in the pipe. When steam is let through the blower, it increases the draft by removing some of the air from the stack and forming a partial vacuum below the nozzle. Fresh air then passes through the fire in order to fill this vacuum, and it is in turn blown out through the stack. The blower nozzle should be turned straight up in order to be effective. It somtimes works loose and turns to one side, or down, and is then of no benefit until straightened. The blower should be used only when the engine is not running. When the engine is running it exhausts through the exhaust nozzle which answers the same purpose as the blower. Some engines have a variable exhaust nozzle, that is one which may be changed from a small to a large opening. The smaller the opening the sharper and stronger the draft, but a small nozzle will cause more back pressure on the engine.

Fire Tools. The fire tools consist of a shovel for coal, a flue cleaner, slice bar, hook, and a hoe. The slice bar is a straight bar flattened at one end, and is used for running through the fire to break up the clinkers when they form, in order to let air pass through the fire. The hook is used for pulling or hooking out the clinkers. The hoe is used for pulling ashes out of the ash-pit and furnace, for pulling the fire when necessary, and for cleaning the fire.

Low Water. In case the water has got below the tubes or crown sheet in a boiler, cover the fire immediately with ashes or any earth that may be at hand. If nothing else is handy, use fresh coal. Then draw it out as soon as it can be done without increasing the heat. Neither turn on the feed water, start or stop the engine, nor lift the safety valve, until the fire is out and the boiler cooled down. After a boiler has cooled sufficiently, it should be examined to see if the tubes and sheets are injured, before firing up again. As long as there is water over the tubes or crown sheet, it is safe to put in more water; but it is never safe to put in water after it gets below the tubes or crown sheet.

An engineer should always watch his boiler closely and notice when the water commences to get low. This is usually caused by the pump or injector refusing to work, or by their not working to their full capacity. In case the water is getting low, the engineer should stop the engine, cover the fire with fresh coal or ashes so as to bank it, close the draft and damper while there is about one inch of water over the tubes. Then set to work to get the pump or injector to work properly. By stopping the engine while there is one inch of water over the tubes or crown sheet, there will be no danger of weakening the boiler, and the water will be kept above the danger line and it will not be dangerous to put in water when the pump or injector commences to work properly. If, however, the engine is allowed to run while the pump or injector is being repaired, the chances are that by the time they get to working properly the water will be too low in the boiler to make it safe to add more water.

Air Leaks. All openings which will admit air to the boiler or flues except through the furnace, should be carefully stopped. Air leaks are frequently the cause of serious loss in fuel. If cold air enters at any other place than through the draft doors, it not only destroys the draft, but cools the furnace and the boiler and wastes fuel. If the boiler is set in brick and the brick cracks, the cracks should be dug out and filled in with new mortar. A new boiler set in new brick should be fired up very slowly, in order to let the brick work dry out without cracking. It is well to start a small fire but not to raise any steam pressure for two or three days.

Any boiler should be fired up slowly when cool. Firing up quickly will heat the brick work on the inside and expand it before the brick work on the outside has time to become heated.

STEAM WHISTLE.

Steam Whistle. The steam whistle is used upon boilers for the purpose of giving signals. A uniform code should be adopted and used, so that those within hearing may understand the signals and know their meaning. The following is a code for the use of engineers in charge of traction engines:

One long continuous blast is given at morning and noon, to indicate the working place.

Two long continuous blasts, with a short interval between them, is a signal that the work of the day is completed, or that the job is completed, as the case may be.

One short blast is to stop.

Two short blasts, with a short pause between them, is to go ahead or commence work.

Three medium short blasts is a signal to those hauling grain to the machine that the machine will soon need grain.

One long continuous blast followed by three shorter ones, is a signal to the water man that water is about exhausted.

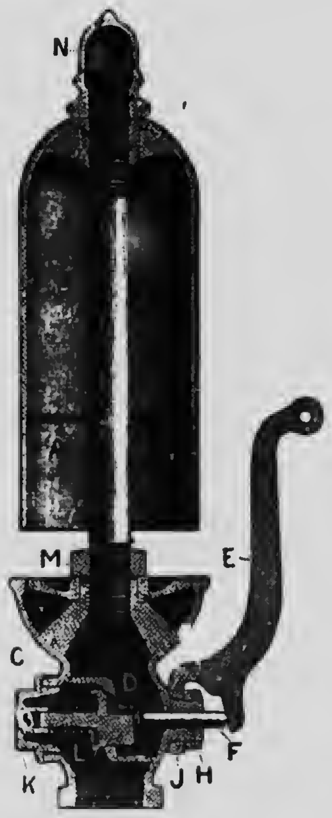


Fig. 24.

A succession of short, rapid blasts is a signal for fire or other distress, and should be responded to by all within hearing.

A sectional cut of a steam whistle is given in Fig. 24 in which A is the bell, B is the whistle stem, and C the whistle body. D is the valve stem, and E is the lever. N is the lock nut for fastening the bell firmly upon its stem. When the lever is pulled the steam escapes through the small opening in the valve body and strikes just inside the bell, causing the whistle sound. If the bell stem D becomes bent, so as to throw the bell out of line with the steam opening, the whistle will not sound properly. The tone of a whistle may be changed by loosening the lock nut N and screwing the bell A down upon its stem, This will make a sharper tone. Raising the bell upon its stem will give a coarser tone.

It is not a good plan to change the tone of a whistle, as a machine is often known by its whistle, and can be more definitely located if it always has the same sounding whistle.

Chime Whistles. Chime whistles are sometimes made with three or more whistles mounted upon the same pipe. They are also made with a single bell with partitions in it.

DUTIES OF THRESHERMEN WITH RESPECT TO:

Prairie Fires. Noxious Weeds. Protection of Public Works.

All of the above subjects affect every Thresherman in Saskatchewan. As the laws relating to them have been amended at some time or other, and will doubtless again be amended, the insertion here of a summary of the regulations with which the Threshermen are required to comply might lead to misunderstandings in the event of the provisions of any statute dealing with these matters being changed. Instead, therefore, of including herein the statutes as they are at present, or a summary of them, it is deemed preferable to request Threshermen to secure from the Department of Agriculture a copy of the Threshers' Account Book, which contains that and much other useful data. The Department prepares each season an account book, which contains extracts from the laws affecting threshing machine operators, and is supplied free to all Threshermen in Saskatchewan annually. If the name of a Thresherman is on the Department's list, a copy of the book will be sent to him each year; but new Threshermen should not fail to have their names placed on that list at the earliest possible date.

Threshers' Lien. Boiler Inspection. Engineers' License.

Included in the book is a supply of lien note forms; so that besides being of value for the laws and information that it contains, the book is in several respects a very convenient one for Threshermen.

It will be sufficient to say that the Department of Agriculture deals with all the matters referred to herein, excepting the inspection of boilers and the granting of engineers' certificates. All these are under the direction of the Department of Public Works, and correspondence relating to them should be addressed to

The Deputy Commissioner,
Department of Public Works,
Regina, Saskatchewan.

For a copy of the Threshers' Account Book, or for any information concerning the regulations governing the operation of threshing machines in Saskatchewan, address

Bureau of Information & Statistics,
Department of Agriculture,
Regina, Saskatchewan.

N. B. It will assist the Department greatly if applicants for the Threshers' Account Book will state whether they own a threshing machine.

PUMPS.

Pumps. We have already learned that the atmosphere or air gives a pressure of 14.7 pounds per square inch at sea level. We have also learned that if we removed all of the air from the inside of a cylinder or pipe, we would produce in it a vacuum. If we remove only a part of the air, we would have a partial vacuum. We have learned, too, that water has weight and exerts pressure. That a cubic foot of water weighs about 62½ pounds. If we divide 62½ pounds by 1,728, (the number of cubic inches in a cubic foot), we would find that a cubic inch of water weighs .0361 pound. Suppose we had a cubic foot of ice. which would weigh practically the same, and were to cut it up into cubes one inch square, and were to take twelve of these cubic inches of ice and place one on top of the other, we would have a column of water one inch square and one foot high. It would weigh 12 times .0361, or .434 pound, which is the weight or pressure per square inch of a column of water one foot high. This pressure increases as the height of the water increases. Were we to double its height, or put on twelve more cubes, it would double the pressure which it gave on one square inch area at the bottom.

The pressure per square inch of water is not affected by the size of the column, or the shape of it, only by the height of the water. A pipe of water 10 inches in diameter and 100

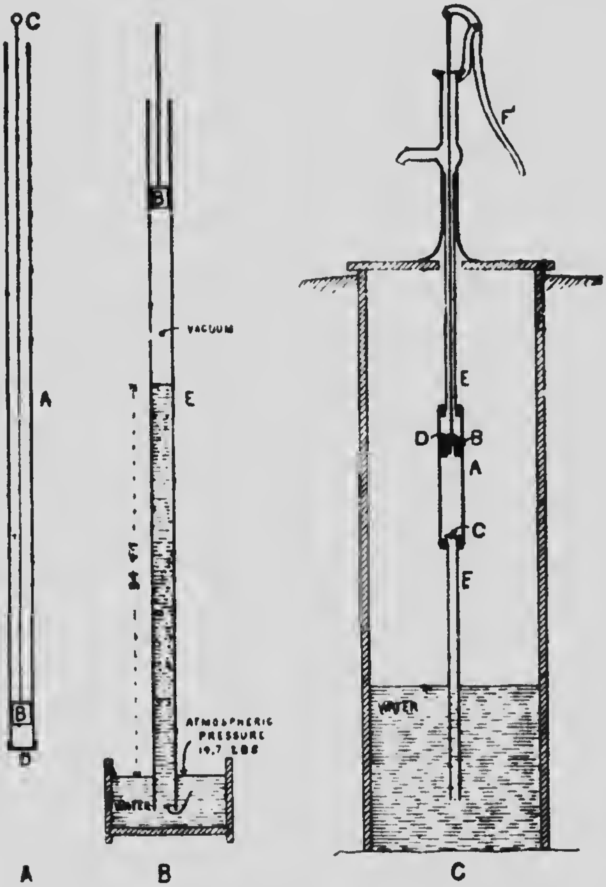


Fig. 25.

feet high, would give the same pressure per square inch as a pipe of water 1 inch in diameter and 100 feet high. It is true that the

10-inch pipe would hold more water, and if we were drawing off a large quantity, we could maintain the pressure better by having a large pipe. But if the water were standing still, or only a very small amount were being drawn, which would not affect the friction of the water in the pipe, the small pipe would give the same pressure as the large one.

If we were to take a cylinder A, Figure 25, 2 inches in diameter and 50 feet high, having the lower end capped air tight, and having an air-tight piston or plunger, B, attached to the handle or rod C, and were to pull up the piston, we would produce below the piston a vacuum. The air on the outside would push against the sides, top and bottom of the cylinder, trying to get in and destroy or fill the vacuum. If we were to remove the cap D, the air would immediately fill the cylinder again, destroying the vacuum. If, however, we were to place the lower end of the cylinder in water before removing the cap, the air could not get in, but would push down on the surface of the water and push the water up the cylinder, until the weight of the water in the cylinder just balanced the weight of the air on the outside, as at E.

We found that one foot of water gave a pressure of .434 pound. If .434 pound pressure will raise or balance a column of water one foot high, 14.7 pounds (the pressure of the atmosphere) will raise or balance a column of water 14.7 divided by .434, or about 34 feet high. If we remove all air and get a perfect vacuum, the water will rise 34 feet. If we do not get a perfect vacuum, (and we do not in practice) the water will rise only a part of the distance, the height depending upon how near an absolute vacuum is secured and the atmospheric pressure.

A common well pump as sometimes put in a shallow well is shown in C Figure 25, the cylinder being placed above the water. A, cylinder, B, plunger, C, receiving valve, D, discharging valve, E, pipe, F, handle. The receiving valve C, and the discharging valve D, both open upward and close downward, like trap doors. Water and air can pass up through each valve, but cannot pass down unless the valves leak, or chips, etc., get under and hold them so they do not close tight. The plunger has a packing on the side and is made to fit air-tight on the sides of the cylinder. When the handle is pushed down the plunger raises the air above it and produces a partial vacuum in the cylinder. The air above the water in the pipe comes up through the lower or receiving valve and fills the cylinder. Water is forced part way up the pipe by the pressure of the air on the water outside. When the handle is raised, the plunger descends and the receiving or lower valve closes and holds the water in the pipe. The air in the cylinder escapes up through the discharging valve. When the handle is again lowered the same action takes place again, until the water finally reaches the cylinder and is lifted out the same as the air was.

After the water is above the cylinder, it can be lifted or forced any height, providing there is power enough to lift it. A pump will not draw water 34 feet, on account of its not being possible to produce a perfect vacuum with a pump. It is not well to put the cylinder more than 25 feet above the water. The closer to the water the cylinder is, the better it will work. It should be put in the water when possible. When in the water it will always be primed, and the pump will run as easily as if placed above the water.

The amount of water a pump will furnish depends upon the diameter of its cylinder, and the speed at which the pump is run. The diameter a cylinder in a well pump should depend upon the height the water is to be lifted. In a shallow well the cylinder may be quite large and the pump not work too hard. But in deep wells it is better to have a smaller cylinder in order to have it work more easily. The larger the cylinder the more water it will throw, but it will take more power to lift it. A cylinder 4 inches in diameter will throw four times as much water as a cylinder 2 inches in diameter, providing both plungers travel at the same speed. It will require four times as much power to lift the plunger in the 4 inch cylinder, as it will to lift the plunger in the cylinder 2 inches in diameter.

For ordinary pumping, the speed of the plunger should not be more than 100 feet per minute. If it be run faster than 100 feet per minute, the cylinder will not fill entirely, the valves will pound more or less, and the pump will not work so smoothly.

Steam boilers are supplied with water by a cross head pump, an independent pump, or an injector. Occasionally an inspirator is used, but they are not in common use. Traction and creamery boilers should have both a pump and an injector.

Cross-Head Pump. A cross-head pump is often used on a traction engine for supplying the boiler with water. The cylinder of a cross-head pump is generally located near the steam cylinder of the engine, and the pump plunger it attached directly to the cross-head of the engine (hence its name), and is driven when the engine is running, the pump making a stroke for each revolution of the engine. This will give the plunger a higher speed than 100 feet per minute, but the cylinder is made small and is designed for a higher speed. The greatest objection to the cross-head pump is that the engine must be run in order to pump water into the boiler. This can be avoided by having an injector attached to the boiler, which may be used when the engine is not running, and for use in case the pump gets out of order.

A sectional cut of a cross-head pump is shown in Figure 26. When the pump plunger B is drawn out of the cylinder A, it produces a partial vacuum in the cylinder, and the receiving valve D opens, the air in the suction pipe J is drawn up into the cylinder. The air pressure on the surface of the water in the barrel forces the water up the suction pipe J. As the plunger is forced into the cylinder, it compresses the air in the cylinder, causing it to close the receiving valve D and open the discharging valve E, forcing the air up through the discharge pipe where it escapes at the petcock H, which should be left open

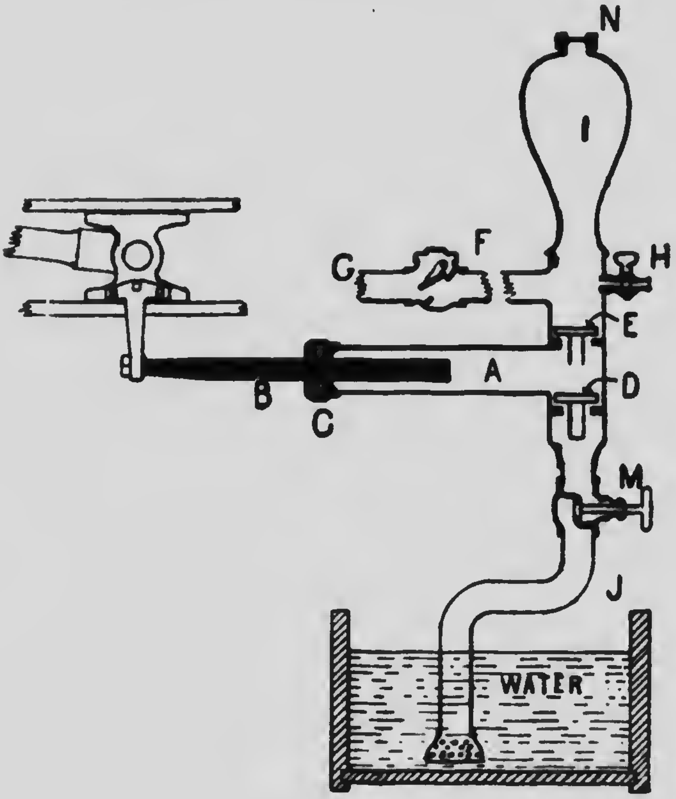


Fig. 26.

until a steady stream of water comes out. The pump repeats this action until water is drawn up into the cylinder and is forced out through the discharge pipe.

When a steady stream of water comes out of the pet-cock H the pet-cock should be closed, when the water will be forced into the boiler through the check valve F and discharge pipe G. The check valve F serves to hold the water in the boiler and prevents it from coming back on the pump, or escaping through the pet-cock H when it is open. The pet-cock is necessary in order to relieve the pump from air when it is starting. In case it is not opened, the air in the cylinder surrounding the plunger is liable to be compressed, and will not have sufficient pressure to be forced through the check valve into the boiler. As the plunger is again drawn back the air will expand, and we will get no action from the pump. The pump would then be what is termed "air bound." The pet-cock should be open until a steady stream of water comes from it, which will prove that the air has been expelled from the pipes and pump cylinder. In pumping warm water, sometimes the pump becomes steam bound in the same manner, and opening the pet-cock will release the steam and the pump will start.

The stuffing box C must be kept well packed with a soft packing, in order to prevent the air from being drawn in between it and the plunger, in place of the air being drawn through the receiving valve and suction pipe.

The Air Chamber. The air chamber I is placed on the discharge pipe near the discharging valve, or between it and the check valve. The object of the air chamber is to secure a continuous flow of water in the discharge pipe. They are made air tight and there is no chance for air to escape. When the discharge pipe is filled with water, part of the water is forced up into the air chamber and compresses the air contained in it. Air under pressure is elastic, and when the pump makes a stroke it produces more pressure on the discharge pipe which forces more of the air into the air chamber. When the plunger starts in the other direction, it relieves the pressure on the discharge pipe. The air then contained in the air chamber will expand and force some of the water through the check valve into the boiler In this way practically a steady stream of water is obtained at all times, and the pump will work easier.

Safety Cap. Nearly all cross-head pumps are provided with a safety cap, located on top of the air chamber at N. This cap has a gasket so arranged in it that in case the pressure increases more than is required to force water into the boiler, the gasket will blow out and relieve the pump, in place of breaking some part. This often occurs in case the hand valve next to the boiler is closed when the pump is started into operation. The water not being able to pass into the boiler, its pressure is raised very high, and is liable to break some of the pipes or fittings unless relieved by a safety cap.

Regulating Cross-Head Pump. The amount of water which a cross-head pump feeds into a boiler is regulated by a valve M on the suction pipe. If this valve be closed entirely the pump will not throw any water. As the pump plunger moves back and forth in the cylinder it produces a vacuum when it is drawn out, and will fill the vacuum itself when it is forced in. If the regulating valve M be opened only a trifle when the plunger draws out, a small amount of water will be drawn through the valve M and partly fill the pump cylinder. When the pump plunger is forced in, it will force this small amount of water into the boiler. The valve should be set when the engine is running so as to keep the water at the proper height, and keep pumping a little all the time. The pump plunger is generally a solid straight bar.

Independent Pump. An independent pump is one that is independent of all other machinery. It [illegible] a steam cylinder and a water cylinder of its own, and may be operated or stopped without interfering with the other machinery. They are often used on threshing engines and creamery boilers. With large sized boilers where a large sized pump can be used, they work very well, but for small threshing or stationary boilers they are made so small, and have so many small steam passages which are liable to choke up, and small parts which are liable to wear and leak steam, that they are very liable to get out of order after a short time.

One of the most common troubles with a small independent pump is from lack of attention on the part of the engineer in keeping it properly oiled. It is as necessary to keep a small pump oiled as it is to keep the engine oiled. If not supplied with oil, it will soon wear, and get out of order. Where a large sized boiler is used, the steam passages in the pump are larger, and the pump is not so liable to get out of order.

Single Acting Pump. A single acting pump is one which throws water one way of the stroke, such as a common well pump which throws water only when the plunger is being raised. As the plunger is lowered, all the water in the pipe and cylinder is stationary. The plunger simply lowers down through the water. A cross-head pump is also a single acting pump. It throws water when the plunger is forced into the cylinder. A single acting pump must have two valves, a receiving valve and a discharging valve.

Double Acting Pump. A double acting pump is one in which the plunger forces water both ways of the stroke. As the plunger is traveling towards one end of the cylinder, it forces the water out of that end and draws it in at the other. As the plunger goes in the other direction, it forces the water out of that end. A double acting pump must have four valves, two receiving and two discharging valves.

Duplex Pumps. A duplex pump is practically a double pump, or two pumps placed side by side. They are often used for the larger steam boilers, and are the most satisfactory pumps to be had. The pumps are placed side by side on the same base, and have the same suction and discharging pipes The slide valve operating one pump is connected to the plunger of the other pump, and they are set so that one plunger will follow the other.

For instance, one plunger will make a stroke, and in doing so will move the slide

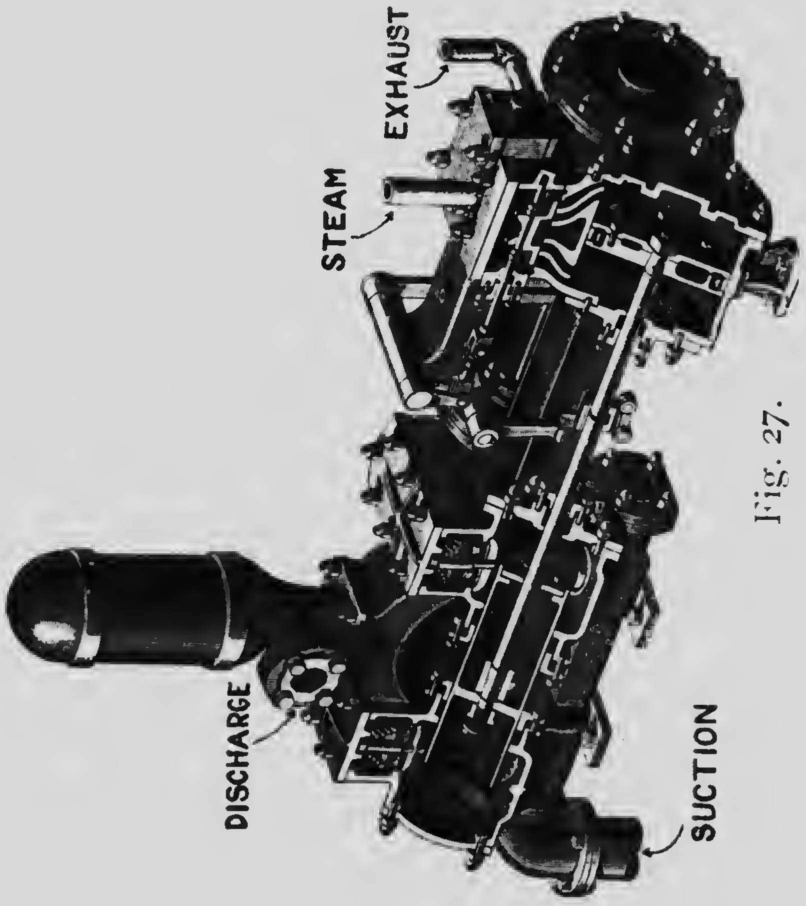


Fig. 27.

valve of the other pump causing it to follow. When the second plunger follows it moves the slide valve of the first plun , when it will then travel in the other direction, and in doing so it moves the slide valve of the second pump again, and the second pump again follows.

By connecting the two pumps together in this manner, the working parts are much simplified and are not liable to get out of order. A duplex pump having a proper sized air chamber will deliver water at a uniform speed. A duplex pump must have eight valves, four receiving valves and four discharging valves. Large duplex pumps often have more valves.

A sectional view of duplex pump is shown in Figure 27.

Regulating Independent Pumps. The amount of water put into boiler with an independent pump is regulated by the speed of the pump. It should be run just fast enough to keep up the supply of water and run steadily. The pump should be large enough to keep up the supply when the plunger is traveling at the rate of 50 feet of piston per minute. Boiler feed pumps are rated at this speed in order that they may be run faster in case the water becomes low.

Belted or Geared Pumps. In many cases it is advisable to supply a boiler with a belted or geared pump. This consists of a cylinder and plunger somewhat similar to a cross-head pump, the plunger getting its motion from a connecting rod and crank which are driven by a belt from a line shaft, or from the engine. In many stationary plants, where the engine is run practically all the time, if water passes through a heater, this is the most economical and satisfactory manner of feeding the boiler.

Regulating Belted or Geared Pumps. The amount of water put into a boiler by a belted or geared pump may be regulated in three ways.

First, by the use of a by-pass valve, which is a valve connected to the discharge pipe between the pump and the feed water heater, and connected with the pipe leading back to the water supply. In case the water is becoming high in the boiler, this valve may be opened a trifle and some of the water allowed to pass back into the water supply again. In this manner a smaller amount is forced into the boiler.

Second, it may be regulated by a valve on the suction pipe. Partly closing the valve will not allow the pump cylinder to fill entirely. The pump will have the same action as the crosshead pump.

Third, by stopping the pump. This, however, is not a good plan, as the water supply is irregular, and is harder on the boiler as it will be alternately cooled and heated when the pump is started and stopped. The height of the water in the boiler will vary, and results will not be so economical.

Economy of Boiler Feeders. It has been proven by experiment that the most economical apparatus for supplying a boiler with water, is the belted or geared pump, run from the engine and feeding the water through a feed water heater. This would also apply to a cross-head pump, as it receives its motion directly from the engine. The following table gives the order in which boiler feeders are classified in the order of their economy:

1. A geared pump run from an engine, feeding through feed water heater.

2. Independent steam pump, feeding through feed water heater.

3. Injector, feeding through feed water heater.

4. Injector, feeding without feed water heater.

5. Direct acting pump, feeding without feed water heater.

Pump Troubles. Pumps to work well must be kept clean, well packed, well oiled, and all joints tight. The following are the most common causes of a pump not working:

1. Chips, straw, dirt, etc., getting under the pump valves or check valves and keeping them from closing tightly. A strainer should be put on the suction pipe where there is any danger from this source.

2. Leaks in the suction hose or pipe. Examine carefully. The air may get in around the valve stem of a suction pipe, or the hose may leak air.

3. The pump may become air bound. Open the air cock at the bottom of the air chamber, or the pet-cock under the check valve until the water starts.

4. The packing on the plunger may be loose or worn and leak air. This packing should always be soft and the box well filled. On an old pump the plunger may be worn so as to be smaller in the middle. If so, take it to a machine shop and have it turned up true.

5. The water may be too hot. No pump will lift hot water, as it is impossible to produce a vacuum above it. As soon as air is removed the water gives off steam or vapor which fills the suction pipe above it. Hot water may be pumped if the pump is placed low enough for the water to run into the cylinder.

In an independent steam pump the trouble of not working may be due to some fault in the steam end, or to some fault in the water end of the pump. If the pump plunger will move back and forth, but refuses to draw or force water, it is a sign that something is wrong in the water end, in the pump valves or water supply; or possibly the packing on the plunger may be worn. If the pump refuses to move back and forth, indications are that something is wrong in the steam end. The gasket packing may not be placed properly, or some of the small steam ports may have become clogged with dirt; or the pump may not be properly lubricated; or it may not have sufficient steam pressure.

A well pump requires new leathers on the plunger occasionally. They can usually be bought pressed into shape ready to go on, or they may be made of valve leather, which is soft sole leather. In making them they should be first cut the proper size, then soaked in warm water to soften them. Screw them on the plunger and force it into the cylinder. If the cylinder can be warmed about as hot as a flat iron it will make a better leather, as the heat will dry the leather and it will retain the cup shape. They should be put on with the soft or flesh side out.

Feed Water Heater. Nearly all traction engines are supplied with a feed water heater, which generally consists of a cast iron box about 4 inches square inside and about 4 feet long, through which the exhaust steam passes on its way out from the engine cylinder. The water pipes from the pump and injector pass through this heater, and the water is warmed by the heat from the exhaust steam.

Considerable saving is made by the use of a feed water heater, as it utilizes the heat from the exhaust steam and does not generally produce any back pressure upon the engine, the steam condensing as it comes in contact with the water pipes. The water pipes usually pass three times through the heater of an ordinary traction engine, the pipe being fitted with a return elbow at each end. There should always be a valve or pet-cock connected to the bottom of the heater, to allow the water formed by the condensation of the steam to escape without being forced up the smoke pipe by the exhaust steam. This valve should always be opened at night in cold weather to drain the heater. The water pipe in the heater should also be drained when there is danger of freezing.

Economy of Heating Feed Water. The following table shows a percentage of saving of fuel effected by heating feed water, steam pressure being taken at 60 pounds pressure. It will be seen from the table that if feed water enters the heater at 32 degrees Fahrenheit. and leaves the heater and enters the boiler at 60 degrees, it would make a saving of 2.39 per cent. If the water entered the heater at 50 degrees and left it at 200 degrees, the saving would be 13 per cent. Where exhaust steam from the engine is exhausted into the atmosphere, it is always more economical to pass it through the feed water heater, thus utilizing the heat of the exhaust steam which would otherwise be wasted.

Jet Pump or Ejector. A jet pump or ejector is a device for raising water or other liquids by using direct steam pressure. They are often used in creameries for elevating skim milk, and on traction engines for filling water tanks, and for fire protection. They work on the same principle as the noiseless water heater shown in Figure 28. Steam is admitted through the jet A. As it escapes from the jet, it draws with it the air from around the

TABLE.

Showing the Percentage of Saving of Fuel Effected by Heating Feed-Water, Steam Pressure 60 Pounds.

Initial Temperature of Feed-Water.

Final Temp. Feed-Water.	32°	40°	50°	60°	70°	80°	90°	100°	120°	140°	160°	180°	200°
60°	2.39	1.71	0.86	0									
80	4.09	3.43	2.59	1.74	0.88	0							
100	5.79	5.14	4.32	3.49	2.64	1.77	0.90	[illegible]					
120	7.50	6.85	6.05	5.23	4.40	3.55	2.68	1.[illegible]0	0				
140	9.20	8.57	7.77	6.97	6.15	5.32	4.47	3.61	1.84	0			
160	10.90	10.28	9.50	8.72	7.91	7.09	6.26	5.42	3.67	1.87	0		
180	12.60	12.00	11.23	10.46	9.68	8.87	8.06	7.23	5.52	3.75	1.91	0	
200	14.30	13.71	13.00	12.20	11.43	10.65	9.85	9.03	7.36	5.62	3.82	1.96	0
220	16.00	15.42	14.70	14.00	13.19	12.33	11.64	10.84	9.20	7.50	5.73	3.93	1.98
240	17.79	17.13	16.42	15.69	14.96	14.20	13.43	12.65	11.05	9.37	7.64	5.90	3.97
260	19.40	18.85	18.15	17.44	16.71	15.97	15.22	14.45	11.88	11.24	9.56	7.86	5.96
280	21.10	20.56	19.87	19.18	18.47	17.75	17.01	16.26	14.72	13.02	11.46	9.73	7.94
300	22.88	22.27	21.61	20.92	20.23	19.52	18.81	18.07	16.49	14.99	13.37	11.70	9.93

outside of the jet and in the pipe B, causing a partial vacuum in the pipe B. When the partial vacuum occurs in the pipe B, the pressure of the air or atmosphere on the surface of the water forces the water up into the pipe B. until the steam catches it at the opening of the nozzle and forces it through the pipe C. The water condenses the steam, and the steam heats the water.

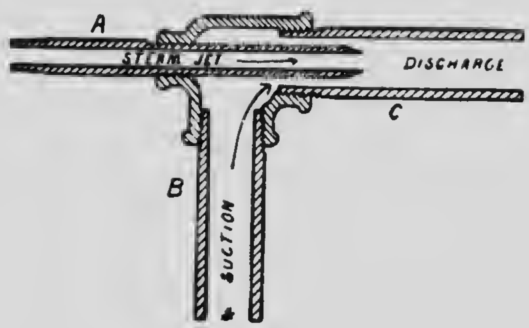


Fig. 28.

The height they may be placed above the water depends upon the temperature of the water and the pressure of the steam. They will not work well when placed over ten to fifteen feet above the water. It is best to place them lower, if possible.

Ejectors are not expensive, are very simple, and, having no moving parts, are not liable to get out of order. They are made in several styles, but are all on about the same principle.

Noiseless Water Heater. The noiseless water heater, Fig. 28, is used in creameries and other places where it is desirable to heat water in an open tank, by turning steam directly into it. The home made one is made from common pipe and fittings, the tee being ¾x¼x¾ inch. The pieces of ¾ inch pipe B and C being about 4 inches long. The piece of ¼ inch pipe forming the jet A has an end thread, and is screwed past the tee, and is filed to a sharp edge on the end. The heater is attached to the end of steam pipe or hose, and put directly into the water to be heated.

As the steam leaves the jet, it expels the water from the pipe C, draws the water in through the pipe B, and forces it out through C. The steam and water are then going in the same direction, and will unite without causing the pounding noise that occurs when the steam is turned directly into water from a hose or pipe.

When steam is turned directly into a body of water, the steam will force the water apart and form steam bubbles, the same as air bubbles are formed when we blow through a straw into a body of water. The cold water quickly condenses these steam bubbles, and the bubble becomes a vacuum. The water then comes together with a loud report.

Pipe fittings are often broken by turning steam into a pipe containing cold water, on account of the water condensing the steam producing a vacuum, and the water coming together with such force as to break the fittings.

INJECTORS.

Injector. The injector is a device for supplying a steam boiler with water. It is so constructed as to draw the water up, heat it, and force it into the boiler. This is accomplished by the energy of a jet of steam from

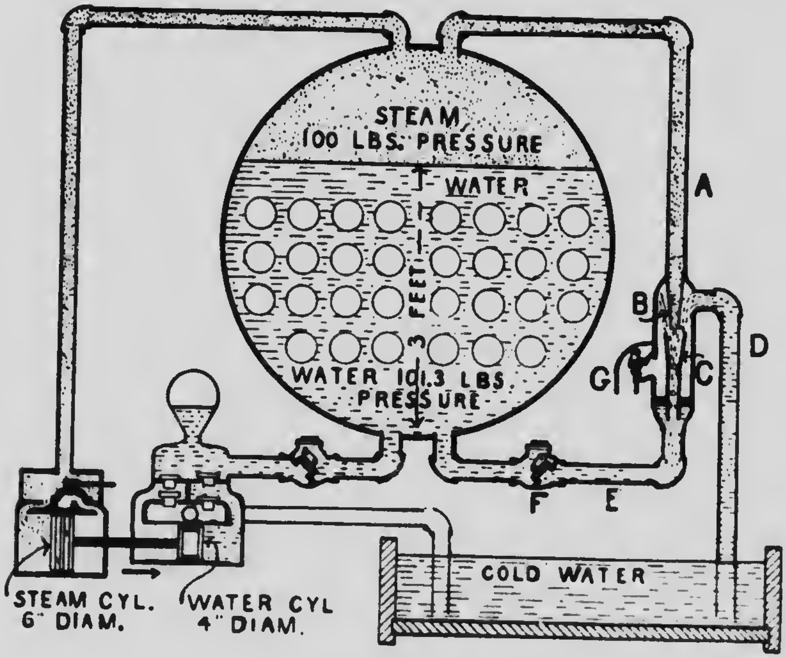


Fig. 29.

the boiler. The injector draws the water up in exactly the same manner that the water is drawn to the ejector or jet pump. It is rather difficult at first thought to understand exactly why an injector should put water into a boiler, as there is more pressure on the bottom of a boiler where the water enters (owing to the weight of the water in the boiler) than there is steam pressure on the top.

In order to make this a little more clear, we will refer to Figure 29, which is an imaginary illustration of a boiler fitted with an injector on one side and a steam pump upon the other. The illustration shows the boiler to have three feet of water in it. The pressure from three feet of water in the boiler would be 3 times .43 or 1.3 pounds per square inch. The steam pressure in the boiler being 100 pounds, would give a pressure of 101.3 pounds on the bottom of the boiler or on the feed pipe. If the steam and water cylinders of the pump were both of the same diameter, it would not be possible for the pump to force water into the boiler, as there would be more pressure upon the water plunger than there would be upon the steam piston. This difficulty is overcome in all steam pumps by making the steam piston larger than the water plunger. In the steam piston we have less pressure per square inch, but have a greater number of inches in the area of the piston than we have in the area of the water plunger. The piston would go in the direction indicated by the arrow, and force the water into the boiler.

It will be noted that as the steam pushes the piston one stroke, it will have taken from the boiler sufficient steam to fill the steam cylinder, and will have pushed into the boiler only sufficient water to fill the water cylinder; or will have removed from the top of the boiler a greater volume of steam than the volume of water returned to the boiler. Were we to turn the amount of water which the pump forces into the boiler to steam at the pressure used, we would find that it would make a much larger volume than required to fill the steam cylinder. It will be noted, then, that we are taking from the boiler a considerable volume of steam at a high velocity and are returning to the boiler a smaller volume of water at a low velocity.

In the injector which is shown on the right hand of the boiler, Figure 29, A shows the steam pipe leading to the injector, B the steam jet, C the combining tube, D suction pipe, E the discharge pipe to the boiler, F the check valve, and G the overflow valve.

When steam is first turned on to the injector, it does not have sufficient force to raise the water and force itself into the boiler, but passes through the body of the injector and escapes through the overflow valve G In doing this it creates a partial vacuum in the suction pipe D and the upper part of the body of the injector. The water rises in the suction pipe until it reaches the steam jet, where it mixes with the steam. The steam then condenses, mingles with the cold water and imparts its velocity to it. When the right proportions of water and steam are received by the injector, it will impart sufficient velocity to the jet of water passing through the combining tube C to enable it to raise the check valve and force the water into the boiler. As soon as this occurs, it produces a vacuum in the body of the injector around the combining tube, and the overflow valve will close. The injector will then be working properly. The object of the overflow is to provide an outlet for the steam and water when they are not mixed in the proper proportions, or when there is not sufficient force to the jet of water to cause it to enter the boiler.

The energy which the steam jet has is derived from the heat given off by the condensation of the steam. The steam escaping through the jet at a high temperature and high velocity, as it comes in contact with the cold water the steam is condensed, its heat is given to the water, and sufficient velocity is imparted to the water to enable it to enter the boiler.

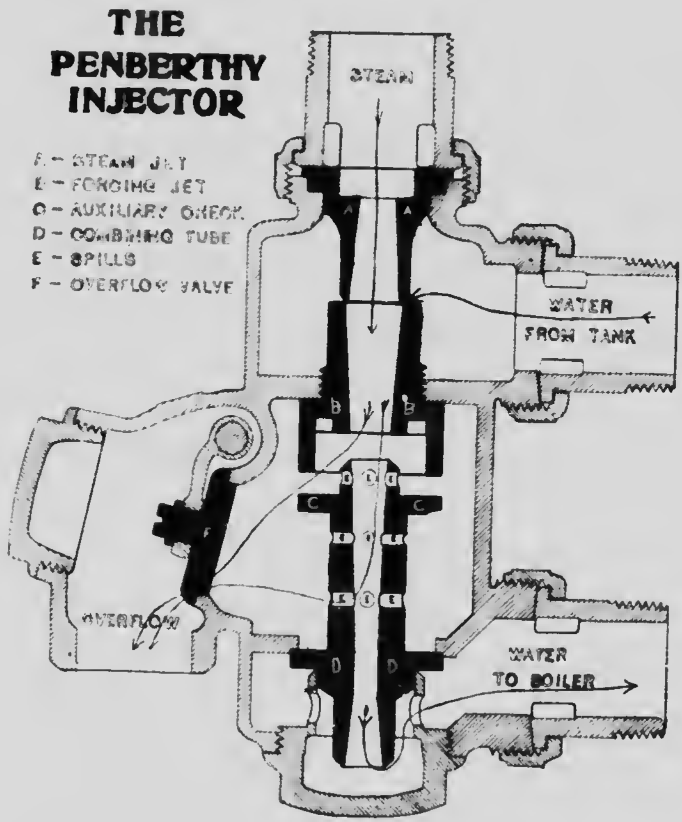


Fig. 30.

Figure 30 is a sectional cut of a Penberthy injector, an injector which is in common use. Injectors are nearly all made on the same principle, and will do good work if properly connected to the boiler, and are kept clean and in good order.

To start the injector when the water supply is below the injector, open the valve on the suction pipe, then open the valve on the steam pipe until the injector starts. To stop the injector, close the valve on the steam pipe. When the water supply is below the injector, it is not usually necessary to regulate or open and close the valve on the suction pipe, as the injector will draw the required amount of water without regulating.

When the water supply is above the injector, as from an elevated water tank, the valve on the suction pipe will need to be closed when the injector is shut off, in order to prevent the water running through the injector.

To start the injector when the water is above it, open the valve on the suction pipe until the water escapes through the overflow. Then open the steam valve and close the valve on the suction pipe until the overflow closes. To stop injector, close steam valve and water valve.

One objection to injectors is that they cannot be regulated to a very great extent. They must feed to nearly their full capacity or not at all. They may be regulated a little by closing down the steam and water valves until they are open just far enough to keep the injector in operation. It usually requires from

30 to 80 pounds of steam to start an injector, depending upon the height it has to draw the water and the condition of the injector. When the injector is in operation the pressure may often be lowered down to 10 or 15 pounds before the injector will stop working.

Injector Troubles. The following are the most common causes of injectors failing to work:

1. Chips, straw, dirt, etc., being drawn in with the water and stopping the jets or openings.

2. Air leaks in the suction pipe or hose, or around the valve stem.

3. The feed water may be too hot. The injectors will not work well with warm water, and not at all with water hotter than about 120 degrees. The colder the water is the better the injector will work. Sometimes when the injector becomes hot and will not start, pouring cold water on it will start it.

4. The injector may be scaled up with lime. Where hard water is used it will form a coating of scale on the inside of the injector, which interferes with its working. This may be removed by letting the injector soak over night in a solution of one part muriatic acid and ten parts water. This solution may be kept in a jar and used several times. The

scale may also be removed by soaking it for some time in kerosene or vinegar, but not so rapidly as when soaked in muriatic acid and water. The scale should not be scraped off with an iron scraper, as the scraping is apt to injure the parts.

5. The overflow valve sometimes becomes scaled over and will not close tightly. To remedy this, remove the cap over the valve, and with a screw driver turn the overflow valve back and forth a few times to grind it in.

6. The valve on the feed pipe next to the boiler may be closed.

Occasionally the check-valve between the injector and boiler will leak and let the hot water from the boiler back into the injector, which will heat the injector and sometimes interfere with its starting.

It is a good plan to have a pet-cock underneath the check-valve in order to drain the check valve and pipe in cold weather, and also to aid in starting the injector. This pet-cock can be left open until the injector has started and is forcing a stream of water out of the pet-cock, when the pet-cock may be closed and the water forced into the boiler.

Steam for the injector should always be taken from the hottest part of the boiler so as to get as dry steam as possible. An injector will not work with wet steam neither will it work well when the boiler is priming or foaming. The supply pipe for an injector should be taken directly from the boiler, and not be connected with any other pipe, such as a pipe running to the engine or safety valve.

Where an injector is the only method used for filling a boiler, it is a good plan to have two injectors of the same kind on hand. In case one gets out of order, the other may be attached in a few moments, as the unions connecting the injectors to the different pipes are interchangeable.

Inspirator. The inspirator is somewhat similar to the injector, but has nearly gone out of use. The injector being much more simple and less liable to get out of order, it has taken the place of the inspirator almost entirely. The inspirator is quite like the injector except that it has two steam jets in place of one. One is called the lifting jet and one the forcing jet. It is about the same as an ejector and an injector connected together, one jet lifting the water and the other forcing it into the boiler. The claim is made for inspirators that they are able to lift water higher than injectors, and will work at a greater range of pressure.

STEAM ENGINES.

Steam engines are machines which convert the power or force of steam into mechanical motion. They are divided into several classes, according to their design and the work that they are required to perform The most common engines are the stationary, or those set upon permanent foundations; marine engines, which are used upon steamships; locomotive, for railways; portable, or those which are capable of being moved from place to place; and traction, which are engines capable of moving themselves from place to place, and drawing loads upon common roads. They are designated by special features in their designs, as follows:

Direct Acting Engines. Direct acting engines are engines in which the piston rod is connected to the crank by means of a connecting rod, the piston moving back and forth in a cylinder. This is the most common form of engine.

Rotary Engines. Rotary engines are engines in which the piston motion is in a circle around the piston rod or shaft. Rotary engines are now coming into common use in large steam plants. Until recently it has not been practical to use rotary engines, on account of their being more wasteful in the use of steam than the direct acting engine, it not being possible to work the steam on expansion to the extent that it is in the direct acting engine. The recently designed turbine engine, however, is so constructed as to derive more benefit from the expansion of the steam and they will [illegible] in prominent place among future [illegible] engines.

Oscillating Engines. An oscillating engine is one in which the cylinder oscillates upon journals or trunnions in order to avoid the use of guide bars and connecting rod, the piston rod being connected directly to the crank.

Simple Slide Valve Engine. The most common form of high pressure engine is the simple slide valve engine, such as is in general use in creameries and on some traction engines. A cut of it is shown in Figure 31.

In order to show the position of the crank and eccentric, as well as the slide valve, steam ports and piston, the slide valve rod and guide are shown as broken off at A, the steam chest, valve and cylinder turned quarter way over so as to have the slide valve on top. In the actual engine the slide valve would be at the side of the cylinder.

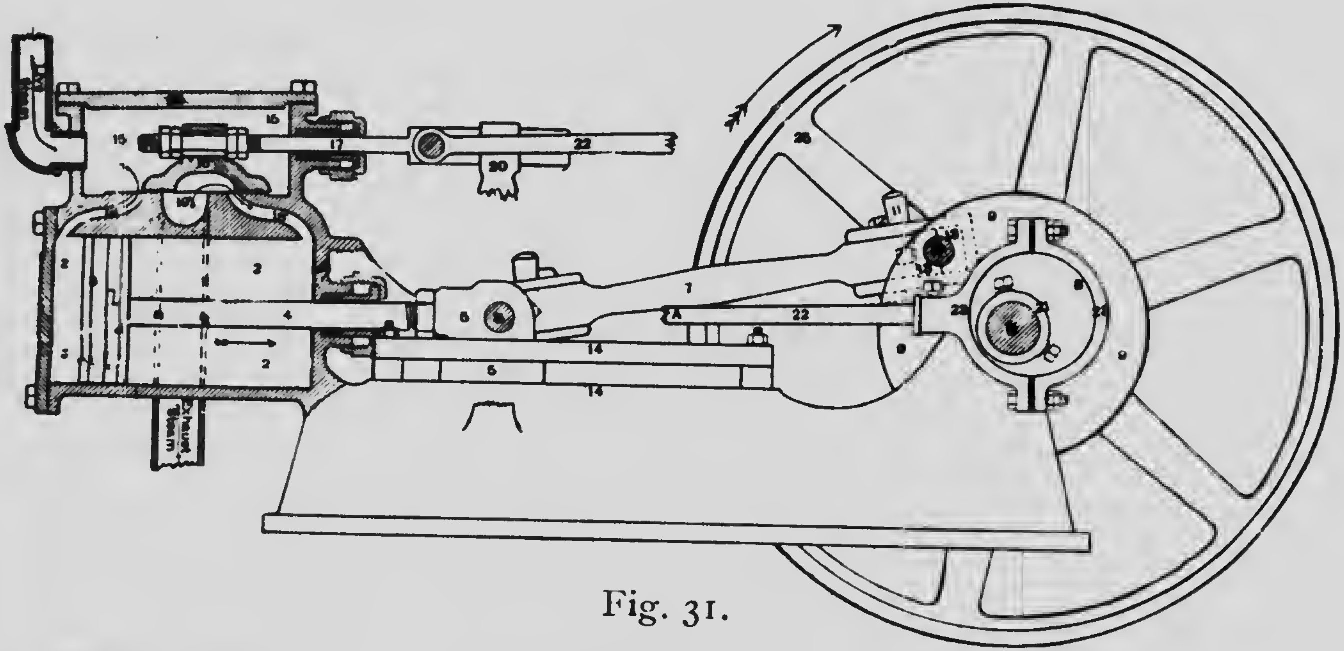


Fig. 31.

1—Engine Frame
2—Cylinder
3—Piston
4—Piston Rod
5—Cross Head
6—Wrist Pin
7—Connecting Rod
8—Main Shaft

9—Crank Disk
10—Crank Pin
11—Key
12—Gib
13—Box or Brasses
14—Guides
15—Steam Chest
16—Slide Valve

17—Slide Valve Rod
18—Steam Ports
19—Exhaust Cavity
20—Slide Valve Rod Guide
21—Eccentric
22—Eccentric Rod
23—Eccentric Straps
24—Cylinder Head
25—Fly Wheel.

Steam from a boiler passes through the governor (not shown) and enters the steam chest, keeping the steam chest constantly filled with steam. Steam enters the cylinder through the steam port (18) and passes through the exhaust cavity (19) into the atmosphere.

As the piston nears the end of the stroke the slide valve is moved by the eccentric so as to close the steam port, thus cutting off the steam. The steam then contained in the cylinder will work on expansion and still push against the piston. When the piston has reached the end of its stroke the valve will have moved over so far that its exhaust cavity will open the steam port into the exhaust port. The other end of the slide valve will admit steam to the other end of the cylinder, and push the piston in the other direction.

The engine is carried past the dead center or end of the stroke by the momentum of the fly wheel. The ports (18 and 18) are alternately used as steam ports and exhaust ports. When either of them is admitting steam it is called a steam port; when it permits steam to escape out of the cylinder, it becomes an exhaust port.

The steam that enters the cylinder while the steam port is open is called live steam.

When the slide valve closes the steam port and the steam in the cylinder expands, it is said to be working on expansion. As soon as the exhaust port opens and allows the steam to escape, it is called exhaust steam.

Eccentric. The slide valve is moved from one end of its stroke to the other by means of an eccentric fastened to the main shaft. The word eccentric means out of center. The eccentric is a wheel having the hole where the shaft goes through it bored at one side of the center. The distance from the center of the wheel or eccentric to the center of the shaft is called the radius of the eccentric, and is equal to one half of the throw of the eccentric.

Throw of the Eccentric. The throw of the eccentric is twice the distance from the center of the eccentric to the center of the shaft upon which the eccentric revolves. It is equal to the distance which the eccentric will move the slide-valve. The eccentric does the same work that a crank would do, the length of the crank being equal to the distance from the center of the eccentric to the center of the shaft. The part of the eccentric which is farthest from the shaft B, Figure 31, corresponds to the crank pin, or the point of movement. When this point is straight up or straight down from the main shaft the eccentric and slide-valve are in the center of their travel. When the point B is on the level with the main shaft on the right hand side, the slide valve will be pulled to the right hand end of its stroke. When the point B is

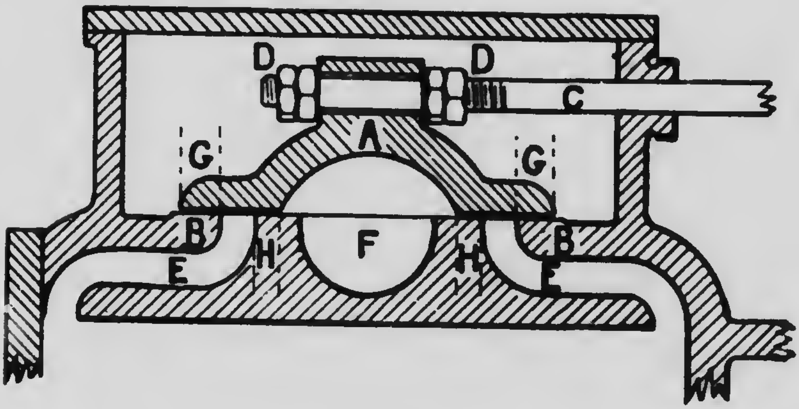


Fig. 32.

A—Slide Valve
B—The Valve Seat
C—Slide Valve Rod
D—Jam Nuts
E—Steam Ports
F—The Exhaust Port.

level with the main shaft on the left hand side, the slide valve will be at the left hand end of its stroke. By noting the position of the eccentric on the shaft, an engineer may tell very nearly the position of the slide valve.

Slide valve. The slide valve of an engine is the valve in the steam chest which moves back and forth, admits the steam, and allows it to escape from the steam cylinder. They are made in many forms, the most common of which is the D slide valve, a section of which, together with steam ports and exhaust ports, is shown in Fig. 32.

Outside Lap. It will be noted that the slide valve is wider than the steam ports, or that it laps over the steam ports on the outside and the exhaust port on the inside. When the valve is in the center of its travel the distance which it laps over the steam ports is called the outside or steam lap, as at G.

Inside Lap. The exhaust lap or inside lap is the amount the slide valve laps over the exhaust port when it is at the center of its travel, as at H.

Object of Lap. The object of lap on the slide valve is to secure the benefit of working steam on expansion. Had the slide valve no lap at all, the steam would be admitted to the cylinder for the full stroke of the engine, and when the piston reached the end of the cylinder, the cylinder would be full of steam at boiler pressure, and the exhaust would open and the steam escape through the exhaust, and no benefit would be derived from working with steam on expansion. This would be very wasteful. On a common slide valve engine the engine is usually designed with the proper amount of lap, so as to cut off the steam when the piston is from about ⅜ to ⅝ of its way to the end of the stroke.

Point of Cut-Off. The point of cut-off is the point in the piston movement at which the slide valve closes the steam port. In a simple engine it is usually between ⅜ and ⅝ of the stroke. A simple slide valve engine has a fixed point of cut-off, or cuts off steam at the same point at all times. In the automatic cut-off engine, it may be earlier or later in the stroke, according to the load of the engine. It cuts off earlier with a light load, and later with a heavy load, the point of cut-off being regulated by the governor.

In a common slide valve engine the point of cut-off can only be changed by moving the eccentric on the shaft, or by putting in a slide valve having more or less lap. Moving the eccentric on the shaft would change the point of cut-off, but it would also affect the "lead" and the time of exhaust.

Balanced Slide Valve. On a simple engine with the plain "D" slide valve, considerable power is consumed in moving the slide valve back and forth upon its seat, due to the steam pressure in the steam chest upon the back of the slide valve. On some of the better class of engines part of this pressure is removed by so constructing the slide valve that the pressure holding it to its seat will be removed. This may be accomplished in several ways, one of which is by putting in what is termed a "piston valve," so constructed that the steam pressure from the steam chest pushes against each end of the valve in opposite directions. This would balance the pressure upon the valve and make it move easily in either direction.

Other balanced slide valves are constructed with a steam cavity inside of the slide valve, where steam enters in place of entering into the steam chest. The slide valve in this case would have steam ports in it, somewhat similar to the steam ports leading from the steam chest to the cylinder. The steam pressure upon such a valve would tend to force the slide valve away from its seat. It is held to its seat by an arrangement which allows only sufficient steam pressure in the steam chest to hold the slide valve firmly to its seat. A balanced slide valve is more expensive to manufacture than the plain, simple "D" slide valve, but when properly constructed will effect a saving in power, at the power required to operate the slide valve would be saved.

Lead. Lead on an engine is the amount of opening which the slide valve allows to the steam port when the engine is on dead center, or when the piston is at the end of its stroke. A simple slide valve should have from 1/32 to 1/16 of an inch lead, and the lead should be the same at both ends. The object of the lead is to admit steam to the cylinder just before the piston reaches the end of its stroke in order to act as a cushion upon the piston, and in order that the steam may be readily admitted to the cylinder during the first part of the stroke.

If an engine has too much lead, too much steam will be admitted to the cylinder before the piston reaches the end of its stroke, and it will cause a loss of power due to the fact that the piston will need to be forced against the pressure by the momentum of the fly wheel. This will have the same effect as applying a brake to the fly wheel. It is also liable to cause pounding on this account.

If an engine has too much lead, it is quite likely that the exhaust port will open too early to obtain the best results from the expansion of the steam in the cylinder.

If an engine has too little lead, not enough steam will be admitted to the cylinder to cushion the piston as it reaches the end of the stroke, and it is liable to "pound" in the cross-head or crank pin, and sufficient steam will not be admitted to the cylinder during the first part of the stroke of the engine. When an engine has too little lead, there is also danger that the exhaust port will not open early enough.

Dead Center. In setting the slide-valve on a steam engine, it is very necessary that the engine be placed on the dead center when the valve is adjusted. An engine is said to be on the dead center when the piston is at the end of its stroke, or when the center of the wrist pin, the center of the crank pin, and the center of the main shaft are all in a straight line. The crank passes two dead centers in each revolution.

If the engine has the proper amount of lead, steam is admitted to the cylinder when it is on the dead center, but the engine will not start when it is on the dead center, as the pressure on the piston will be pushing or pulling directly against the crank shaft. Locomotives, hoisting engines, and other engines, are often made with two cylinders and cranks connected to the same shaft, one crank a quarter of a revolution ahead of the other in order to always have one crank off the dead center, thus enabling them to start at whatever point the engine may have stopped.

It is very necessary when setting the slide valve to put the engine on the exact dead center. This should be done accurately, as a very little difference either way will make considerable difference in the valve. It will be noted that while the engine is on dead center, a little movement of the crank up or down has very little effect upon the piston, as the piston moves very slowly while the crank is passing the dead center. The motion of the slide valve, however, when the engine is near the dead center, is considerable, as it is controlled by the eccentric, and the eccentric is set a little more than a quarter of a turn ahead of the crank. It will be noted, then, that when the piston is traveling at its slowest speed near the end of the cylinder, the slide valve will be traveling at its fastest speed, and any movement of the crank up or down which would have a slight effect upon the piston, would have considerable effect upon the slide valve.

There are several methods of putting an engine on the dead center. About the simplest and most accurate method is with the tram, a tram being simply a rod with a point at each end turned at right angles.

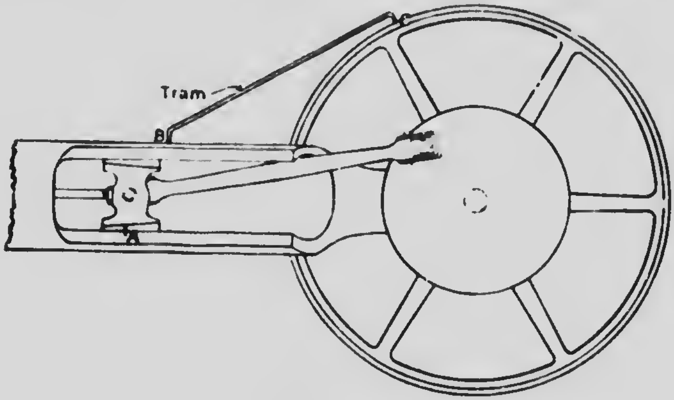


Fig. 33.

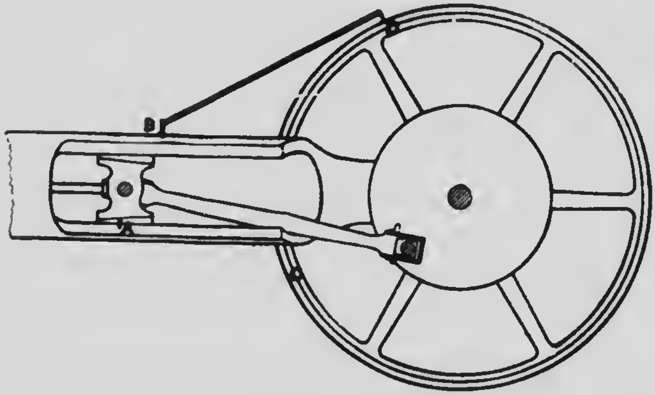


Fig 34.

To put an engine on the dead center with a tram, turn the engine about ⅛ of a revolution off the center, and with a sharp knife make a mark on the cross-head and guide, as at A, Fig. 33.

At some convenient point on the engine frame make a mark, (best with a sharp center punch) as at B. Then with a tram, which may be of any convenient length, place one end at the center punch mark B, and with the other end make the mark on the fly wheel as at C. Now turn the fly wheel over on the other side of the dead center until the marks on the cross-head and guide come together again,

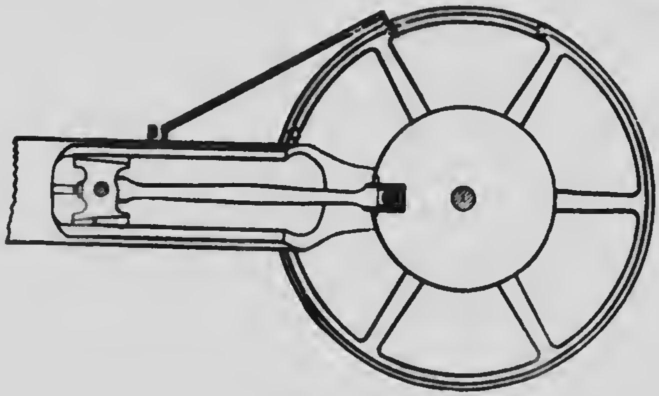


Fig. 35.

which will place the crank position as shown in Fig. 34, or as far below the center as it was above the center in Fig. 33. With the same tram make another mark on the fly wheel, as at D. Now measure on the fly wheel and find a point half way between C and D, as at E, Fig 35. and turn the wheel until this mark is even with the tram. The engine will be on the dead center. Make a permanent mark on the fly wheel at E. By keeping the tram it will be very easy at any time to put the engine on dead center, by simply turning it to fit the tram. After the permanent mark E is made on the fly wheel, it is not necessary to preserve the marks on the cross-head

The other dead center may be found in the same way by placing the engine near the other dead center and marking the cross-head at the other end, or it may be found by measuring half way around the wheel from E, and turning that point to fit the tram.

Occasionally a crank disk is used in place of the fly wheel, it sometimes being more convenient to take measurements from.

In making the tram it is well to make it some definite length, such as twelve or eighteen inches from point to point. In case the tram gets lost at any time, another one may be made the same length and it will fit the marks upon the engine.

Setting Slide Valve. To set the slide valve of a simple engine, have the engine hot, remove the cover from the steam chest in order to get at the slide-valve, put the engine on the dead center, and turn the high part of the eccentric 90 degreess, or a quarter of a revolution, ahead of the crank, in the direction the engine is to run. Place the slide valve in the center of its travel and fasten it to the slide valve rod. Now turn the eccentric in the direction the engine is to run, until the desired amount of lead is obtained (about 1/16 of an inch). Fasten the eccentric to the main shaft and turn the engine on the other dead center to see that it has the same amount of lead at the other end. If the lead is the same at both ends, the valve will be properly set. If there is more lead at one end of the slide valve than at the other, it must be made even by moving the slide valve on the rod one-half of the difference between the leads. If the engine then has too much lead, move the eccentric back towards the crank until the right amount is obtained. If the engine does not have enough lead, move the eccentric ahead, or away from the crank, to get more lead.

The lead of an engine must always be made even on both ends, by moving the slide valve on the rod.

Moving the eccentric changes the lead at both ends of the slide valve. Turning the eccentric ahead, or away from the crank, will give more lead at both ends. Turning the eccentric back towards the crank, will give less lead at both ends. A vertical engine should have a little more lead on the lower end than it has at the upper end, as the weight of the rods, crosshead and piston requires more cushion on the lower end.

The above rule for setting the slide valve applies to the simple slide valve engine that has no rocker arm, and also to engines having a rocker arm pivoted at one end.

Rocker Arm. Some engines are so designed that it is not possible to connect the eccentric rod to the slide valve rod direct, owing to the location of the slide valve, and in order to make connection in the proper manner the rocker arm is made use of. When the rocker arm is pivoted at one end, and the slide valve rod and the eccentric rod are connected near the other end, the position of the eccentric would be the same as in the simple engine.

Some engines are designed with a rocker arm pivoted at the center, the eccentric rod connected to one end of the rocker arm, and the slide valve rod to the other. In this case the slide valve rod and the eccentric rod move in opposite directions, and in order to give the valve the proper motion the eccentric should be turned exactly half way around on the shaft from the position it would occupy in case no rocker arm was used. In setting the slide valve on an engine using a rocker arm pivoted at the center, the eccentric would be turned three-quarters of a revolution ahead of the crank to place the valve in the center of its travel, and would then be moved enough farther ahead (the direction the engine is running to give the required lead.

Angle of Advance. On a simple slide valve engine, when the valve is properly set and the engine is on dead center, the eccentric will be a little more than one-quarter of a revolution ahead of the crank. Were the eccentric exactly a quarter of a revolution ahead of the crank at this time, the slide valve would be in the center of its travel, the engine would have no lead, and steam would not be admitted to either end. In order to get lead the eccentric is turned ahead on the shaft (the direction the engine is to run) until the proper amount of lead is obtained. The amount that the eccentric is turned more than a quarter of a turn ahead of the crank, varies with the different engines from about 10 to 20 degrees, and is called the angle of advance.

Reversing an Engine. To reverse a simple slide valve engine, remove the steam chest cover so as to note the position of the valve.

place the engine on dead center, loosen the eccentric and turn it about one-third of the way around on the shaft in the direction the engine was running, until the slide valve has the same amount of lead at the same end it had before. Fasten the eccentric to the shaft. In reversing the engine it is not necessary to change the slide valve upon its rod, or the length of the valve rods. All that is necessary is to change the position of the eccentric upon the shaft.

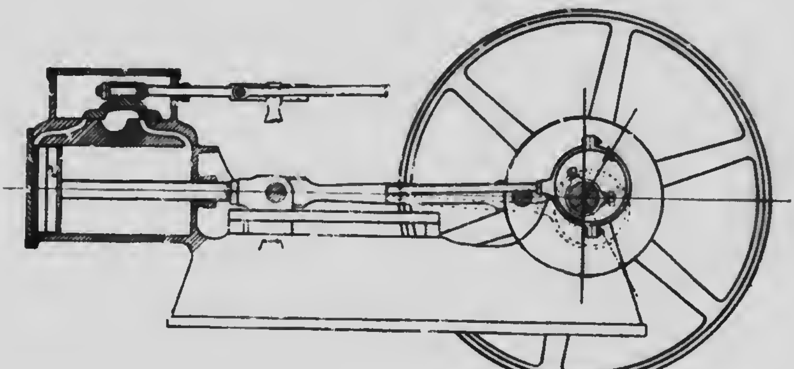


Fig. 36.

Always be sure that the lead is on the same end that the piston is on, and the eccentric so set that when the engine is turned in the direction it is to run, the valve will open the steam port. It will be noted that when the engine is on dead center it must have steam on the same end the piston is on, no matter which way the engine is to run.

A simple engine is reversed, or made to run in the other direction, by changing the position of the eccentric on the engine shaft. Fig. 36 shows an engine with the slide valve set to run ahead or over. The dotted lines show the position which the eccentric would occupy were the valve set to run backwards or under. The valve rods and connections are the same length in each case, the only difference being the position of the eccentric on the shaft. The part of the eccentric farthest from the shaft A may be called the point of movement, and the valve will move in the same direction that the point A moves. When the point A is straight above or straight below the main shaft, the eccentric will be in the center of its travel, and when at that point the valve will be in the center of its travel, if properly set, and will cover both steam ports equally. Turning this point A ahead in the direction the engine is to run, gives the engine "lead."

REVERSE GEARS.

Reversing Gears. Engines that require to be reversed frequently and when in motion, such as locomotives and traction engines, are provided with a reverse gear, or an arrangement by which they may be reversed by simply moving a lever. When the top of the fly-wheel moves away from the top of the steam cylinder, the engine is said to be running ahead, or over. When the top of the fly-wheel moves back towards the top of the steam cylinder, the engine is said to be running backwards, or under. An engine is as strong running in one direction as it is running in the other. An engine appears better, however, when set so as to run ahead or over, and the cross-head will not be so likely to pound up and down between the guides. When an engine is running ahead, the pressure on the cross-head from the piston and connecting rods is always down upon the lower guide. When the engine is running backwards, the force of the piston pushing against the connecting rod tends to raise the cross-head against the upper guide, and the cross-head is more liable to pound up and down between the guides than it is when running ahead.

Link Motion Reverse. The reverse gear that is probably in most common use is termed "link motion" reverse, and is shown in Fig. 37. (In this cut the cylinder is shown as dropped below the shaft in order to show the position of the crank pin, main shaft and eccentric. In an actual engine it would be at the side of the slide valve and in line with the main shaft.)

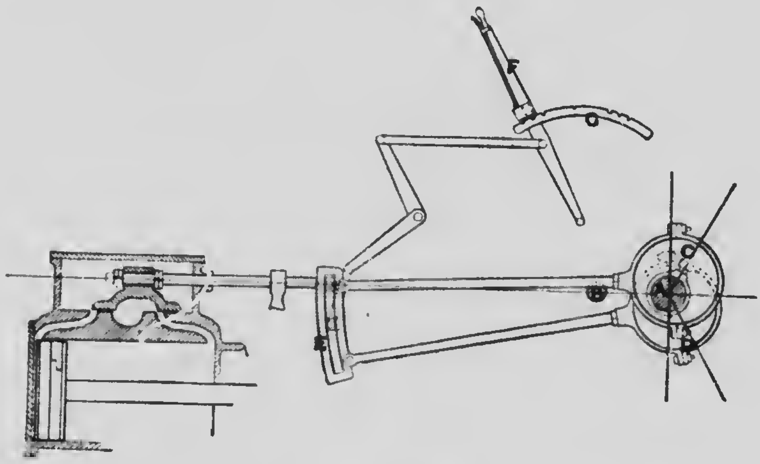


Fig. 37.

A—Main Shaft
B—Crank Pin
C—Forward Eccentric
D—Back Eccentric
E—Link
F—Reverse Lever
G—Quadrant.

It consists of two eccentrics fastened to the main shaft, one set to run forward and one set to run backward. The eccentric rod from one eccentric is fastened to one end of the link, the other eccentric rod is fastened to the other end of the link with the valve rod, and the other one thrown out of line with the valve rod, where it plays back and forth and will have no effect upon the movement of the valve. When the reverse lever F is in the center notch of the quadrant, the engine will not run, as one eccentric will move in one direction while the other moves in the other direction, and gives the valve only a small amount of travel, not sufficient to open the steam ports.

To set the slide valve on link motion, place the lever at one end of the quadrant and set the eccentric rod in line with the valve rod so as to run the engine in one direction, the same as in setting the simple slide valve. When one eccentric is set, place the lever at the other end of the quadrant and set the other eccentric so as to run the engine in the other direction.

An engine provided with the link motion, and not working up to its full power, may be made to cut off the steam earlier in the stroke by setting the lever about an inch or more from the end of the quadrant, which will give the slide valve less travel, cut the steam off earlier in the stroke, and allow it to expand more in the cylinder, which will be more economical in the use of steam. When the reverse lever is set up an inch or two from the end of the quadrant, it is what engineers term "hooked up a little." An engine should be run hooked up a little when doing light work, as it will be more economical in the use of steam and fuel. In case a heavy load is put on, more power can be obtained from the engine when the lever is put down to the last notch.

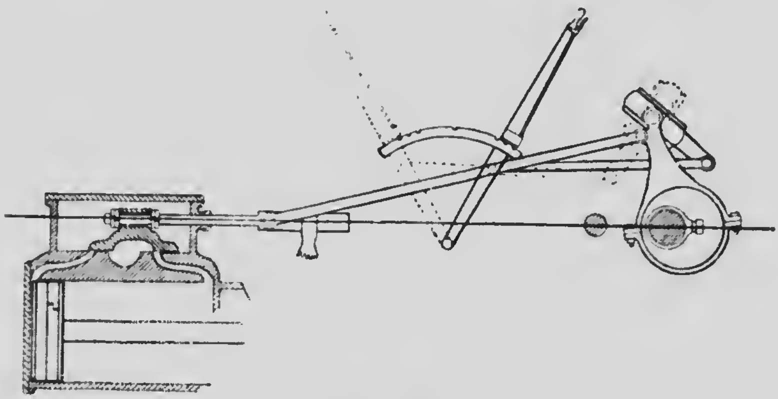


Fig. 38.

Single Eccentric Reversing Gear. The Woolf reverse gear, Fig 38, also termed the single eccentric reverse gear, is in quite general use and gives good results. It has few parts to wear and become loose, and may also be set so as to cut the steam off earlier or later in the stroke, according to the load on the engine. With this reverse gear the throw of the eccentric is set opposite to the crank pin. The engine is reversed by moving the lever from one end of the quadrant to the other, this turns the slot or cam in which the roller in the upper end of the eccentric slides into the position shown by the dotted lines, and will cause the slide valve to move in the opposite direction. With this reverse gear, when the engine is on dead center and the eccentric properly set, moving the reverse lever from one end of the quadrant to the other, will not move the slide valve.

Other Reversing Gears. There are several reversing gears in use upon engines, but the two named above are in most common use. All types of reverse gears consist of some arrangement which is equivalent to changing the position of the eccentric upon the shaft. By understanding the principle of the common eccentric thoroughly, it will be comparatively easy for an engineer to study out the working of other types of reverse gears.

Clearance. Generally speaking clearance is the space in the steam cylinder between the piston and cylinder head, when the engine is on dead center. Strictly speaking, clearance is all of the space contained between the end of the cylinder and the piston, when the engine is on dead center; also the space contained in the steam ports up to the face of the slide valve. Some engine builders allow more clearance on an engine than others, the amount of clearance depending upon the design of their engine, and upon their judgment as to how much clearance an engine should have. An engineer cannot change the total amount of clearance on an engine without putting in a different piston. If the piston is not screwed into the cross-head the proper distance, the engine is liable to have more clearance on one end than upon the other. An engine should have equal clearance on both ends.

To find if there is equal clearance on both ends, put the engine on each dead center, and mark the cross-head and guide at each end. which will show the travel of the cross-head when the engine is running. Then disconnect the connecting rod from the crank pin, and pull the piston ahead until it strikes the end of the cylinder, and notice how far the mark on the cross-head comes past the mark on the guide. This will show the amount of clearance on the crank end. Now push the piston back until it strikes the head end of the cylinder, and see if the mark on the cross-head comes the same distance past the mark on the other end of the guide. If it does, the clearance on both ends will be equal.

GOVERNORS.

Governors. In order to secure a steady motion from a steam engine, it is necessary that some arrangement be made for regulating the amount of steam applied to the cylinder and piston. Engines that do not require a steady speed, such as the locomotive and steamboat engine, are not usually equipped with a governor, the speed of the engine being controlled by the engineer in charge opening or closing the throttle-valve. The throttle-valve is the valve between the boiler and the engine where the steam is turned on or off from the engine.

Engines are divided into three common types according to their governors. Throttling Engine, Automatic Cut-off Engine, and Corliss Engine, each of which has its distinct type of governor. The governor in common use upon traction and creamery engines, is the throttling governor. Engines equipped with governors of this type are said to be throttling engines.

Throttling Governors. On an engine equipped with a throttling governor, the slide-valve has a fixed point of cut-off, the slide-valve traveling the same distance at all times. The speed of the engine is regulated by the amount of steam which the governor allows to pass through it. This regulates the pressure of the steam in the steam chest.

For instance, a large engine that has a throttling type of governor, when doing a small amount of work, might have steam on its boiler at say 100 pounds pressure. The governor would cut this steam pressure down as it enters the steam chest to perhaps 15 or 25 pounds, or whatever pressure is required to keep the engine at the desired speed. In case the speed of the engine fell below the required speed, the governor would open a trifle and admit more steam into the steam chest and cylinder. If the speed of the engine should increase, the governor would close a trifle and decrease the pressure of the steam in the steam chest. On an engine equipped with this type of governor, it is not possible to work steam on expansion to the same extent that it is in an automatic cut-off or Corliss engine.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

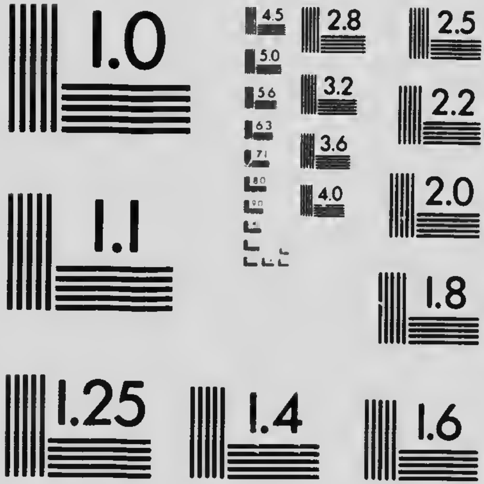


Figure 39 is a sectional cut of a throttling Gardner governor, such as is in common use on stationary engines. The governor is usually placed upon the steam chest of the engine. Steam passes through the governor

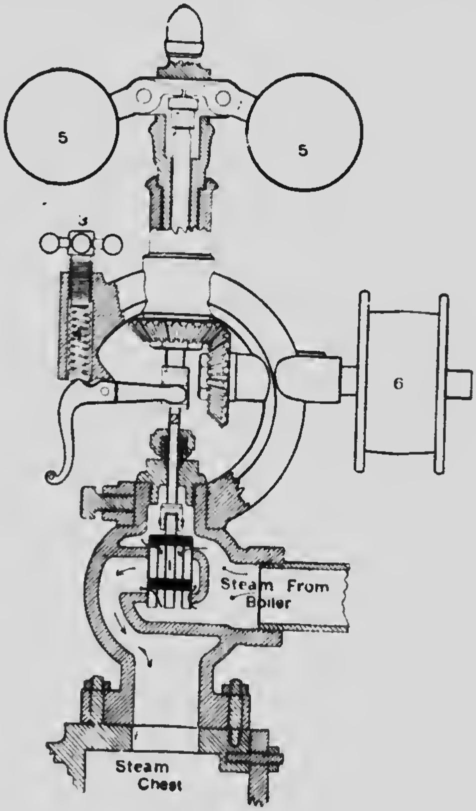


Fig. 39.

valve (1) in the direction indicated by the arrows. The valve in a governor is so constructed that steam pressure will have no effect upon its opening or closing. It will be noted from the cut that the steam presses on the top of the valve as well as on the bottom, giving an equal pressure on both sides. The valve is raised or lowered in its seat, to allow more or less steam to pass through it, by the valve stem (2) which extends up near the top of the governor. The valve stem is held up and the valve open by the spring (4) pressing down upon one end of the lever, the other end of the lever raising the valve and stem. The tension of the spring and the speed of the governor is regulated by the hand wheel (3). When the governor is at rest the valve is wide open, and the governor balls (5), which are hung upon pivots, are dropped at the side of the governor.

The power which operates the governor and controls the speed of the engine, is carried from a pulley upon the main shaft of the engine to the governor pulley (6). The motion is then carried through the pulley shaft and by means of gear wheels up to the governor balls, and causes them to revolve upon their stem. When the governor is in motion, the balls revolving tend to swing outward and upward turning upon the pivots from which they are suspended. In doing this the end of the lever on which the balls are hung presses downward upon the top of the valve stem, partly closing the valve and decreasing the amount of steam which the governor lets through into the steam chest. In case the speed of the engine decreases, the speed of the governor will decrease and the balls will lower their position, allowing the valve stem to rise and admit more steam to the steam chest.

To increase the speed of the engine, screw down the handwheel (3), which will increase the tension on the spring and require more speed from the engine and governor before the balls will rise sufficiently to shut off steam from the steam chest.

To decrease the speed of the engine, screw up the handwheel (3), which will release the spring and allow the valve to be forced down with less speed of the engine.

Governor Belt Off. When the governor belt is taken off the pulley, the governor will open wide and remain in that position, giving the same effect that would be had were there no governor upon the engine. The engine is then controlled entirely by the steam pressure regulated by the throttle-valve. When the engineer has hold of the throttle and controls the steam admitted to the steam chest, and does not allow the engine to run too fast, it would have the same effect that the governor would have with the belt on. It is not a good plan, however, to remove the governor belt, as the engineer is liable to give the engine too much steam and run it at too high a speed. Running it at a high speed causes a severe strain upon all of the bearings and parts of the engine. The governor belt should always be left on. If it is desired to increase the speed of the engine, adjust the regulating screw of the governor to the required speed. Any traction engine will travel as fast as the manufacturers have designed that it should travel when the governor belt is on.

Engine Racing. An engine is said to be racing when the speed of the engine increases and then decreases while the engine has the same load upon it. This is usually caused by some trouble with the governor. The most common trouble is from the governor valve stem being packed too tight. When it is packed too tight the packing binds upon the stem, and it will require considerable force from the balls before they will force it down. After they have forced it down, the speed will decrease, and will sometimes decrease considerably before the pressure from the spring will raise it to admit steam again. The valve stem should be packed quite loosely in order to give the governor perfectly free play up and down. It should be packed with a soft packing, and the packing renewed frequently before it hardens.

Occasionally an engine will race from the governor not being packed firmly enough. If an engine races, try loosening the packing until the governor is perfectly free. Then if it does not stop, tightening the packing a trifle will sometimes remedy it.

A governor will race in case it is not properly oiled. The pivots upon which the balls swing should be oiled, also the shaft upon which the balls revolve, and the shaft carrying the pulley wheel.

A governor will also race if the governor belt is too loose and slips.

In starting an engine, always turn the steam on slowly until the governor gets into operation and controls the speed of the engine. The throttle-valve should then be opened wide, the speed of the engine be controlled by the governor.

Automatic Cut-Off Governor. A steam engine equipped with an automatic cut-off governor is usually termed an automatic cut-off engine. The word automatic means self-moving or self-regulating. The term automatic cut-off, would mean a self-regulating cut-off engine.

As previously stated, the slide-valve on an engine controlled with a throttling governor usually has a fixed travel, and cuts off steam at the same point regardless of the speed of the engine, or power required. In an automatic cut-off governor the travel of the slide-valve is regulated by the governor which is located in the fly wheel of the engine. They are constructed in several different ways, but work on practically the same principle.

The eccentric in an engine governed in this manner is not fastened to the shaft, but has an extending arm upon one side, which is fastened to and pivoted upon a pin carried by the fly wheel. The central part of the eccentric is cut out so as to enable the eccentric to move freely across the shaft of the engine. An arm also extends from one side of the eccentric and carries a link extending to one end of a lever which carries the controlling weight and spring. The controlling weight is so placed upon the lever that when the fly wheel is in motion the controlling weight has a tendency to fly out towards the rim of the fly wheel, carrying with it the lever upon which it is secured. As the weight is thrown out towards the edge of the fly wheel, the lever and link connecting the arm of the eccentric force the eccentric into a more central position with the shaft, or, in other words, decrease the throw of the eccentric. When the throw of the eccentric is decreased, the travel of the slide-valve of course is less. When the travel of the slide-valve is shortened, it will not open the steam ports so wide and will close them quicker, and in this manner decrease the amount of steam admitted to the cylinder.

It will be noted, then, that in the automatic cut-off governor, the travel of the slide-valve depends altogether upon the work which the engine is doing.

In an engine governed with this type of governor, steam in the steam chest is always at boiler pressure. The steam admitted to the cylinder while the steam port is open is admitted at boiler pressure. When steam is admitted to the cylinder at boiler pressure, and cut off early in the stroke, more benefit is derived from the expansion of the steam in the cylinder. In an engine controlled by an automatic cut-off governor, the speed of the engine will be governed very closely, as the governor is more sensitive and acts more directly than the throttling governor.

A cut of a fly wheel carrying an automatic governor and eccentric, is shown in Figure 40. The full lines in the cut show the posi-

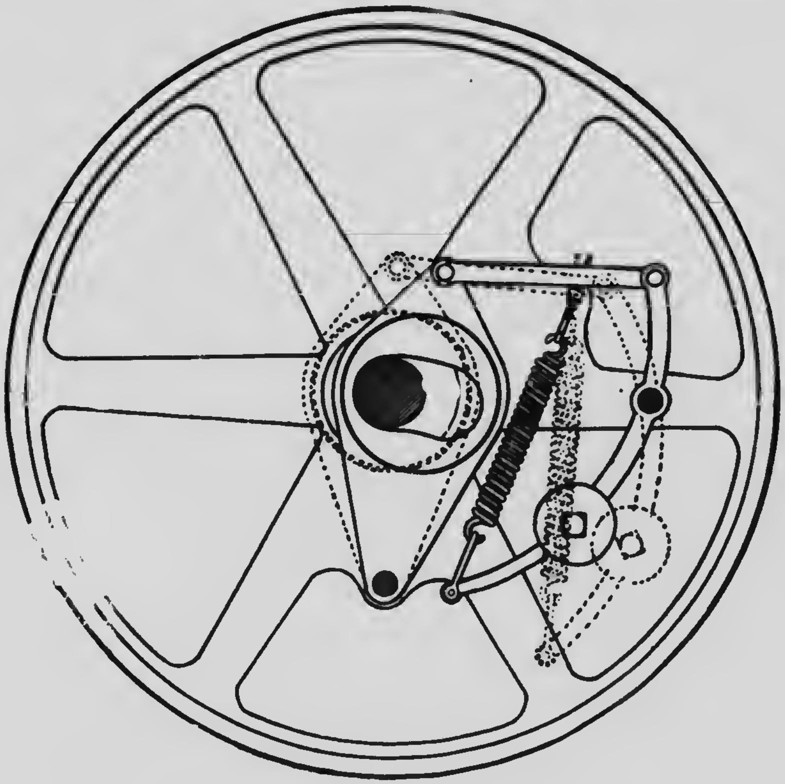


Fig. 40.

tion of the eccentric, governor, lever, weight and spring, when the engine is at rest or is working at full load. The dotted lines show the position of the eccentric, lever, weight and spring when the load upon the engine is very light. The governor will work between the two positions shown. It will be noted that when the eccentric occupies the position shown by the dotted lines, it would give very little travel to the slide-valve.

The speed of an automatic cut-off governor is regulated by the weight upon the lever and the tension upon the spring.

To increase the speed of the engine, move the ball upon the lever towards the pivot on which the lever turns, or increase the tension upon the spring.

To decrease the speed, move the ball upon the lever towards the end of the lever, away from the pivot upon which the lever swings, or decrease the tension upon the spring.

It is not possible to change the speed of an engine controlled with an automatic governor while the engine is in motion. An engine controlled with a governor of this type is very sensitive and usually runs at a high speed. The governor and eccentric must be kept in good order so as to work properly. They are not in common use upon traction engines or on small size stationary engines such as are in creameries, being in more common use on small size electric lighting plants and places of similar nature, where a steady speed is required at all times, and where it is desired to use steam as economically as possible.

Corliss Governor. The Corliss engine, named after its inventor, is an engine having two steam valves and two exhaust valves, in place of the ordinary slide-valve. The steam valves are usually located at the end of the cylinder and very close to it, giving a very short steam port. The exhaust valves are also located at the end of the cylinder. These valves are connected with rods to a wrist plate mounted upon a pivot on the side of the cylinder, and receive their motion from the wrist plate. The wrist plate, in turn, receives its motion from the eccentric on the main shaft, which is similar to the eccentric on the simple slide valve engine. With an arrangement of this kind the steam and exhaust valves may be set independent of each other.

The steam valves are constructed so as to be opened by the motion from the wrist plate, and when the engine is first starting and until controlled by the governor, the engine takes steam nearly the full stroke. When the speed of the engine reaches the desired point, the governor gets into action and regulates the

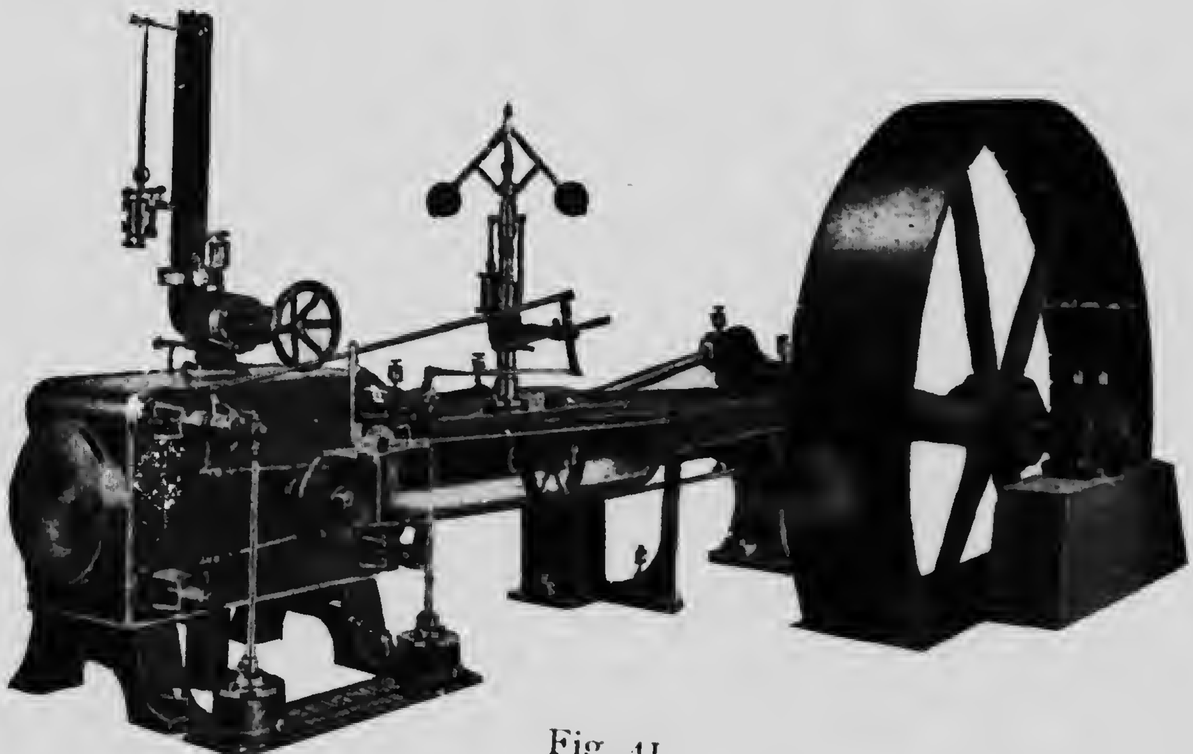


Fig. 41.
Standard Single-Cylinder Girder Frame Corliss Engine.

time of closing, or point of cut-off, of the steam valves, closing them earlier or later in the stroke according to the work of the engine.

The valves on the Corliss engine are closed by the action of a mechanism called the vacuum dash-pots and dash-pot rods. The dash-pots are located at the side of the engine, usually near the floor, and consist of cylinders with tight-fitting pistons or plungers connected to the dash-pot rods. When the steam valve is open the dash-pot plunger is raised, causing a vacuum in the lower end of the dash-pot. The valve is held open until it is released from the valve gear by a block controlled by the governor. When this block releases the valve, the vacuum dash-pot will pull the valve closed quickly. The governor on an engine of this kind controls the position of the releasing block, and in that manner the time the valve will close. With this type of governor steam is admitted to the engine at boiler pressure, and is cut off at the proper point to maintain the required speed upon the engine. The point of cut-off on a Corliss engine might vary from scarcely admitting steam at all to admitting it at full stroke. In order to secure the best results the engine should cut off at about one quarter of the stroke, or earlier.

The advantages of a Corliss engine are, that it is capable of maintaining a steady speed at a great variation in the load, that it will govern quickly, and will develop more power from a given amount of steam, on account of the benefit derived from working the steam on expansion. They are the most economical engine to be had.

The disadvantages of a Corliss engine are its first cost and the comparatively large space which the engine must occupy. On account of its construction it is necessary that an engine of this kind have a comparatively slow speed, and in order to develop the required power it is necessary to make the cylinder, connecting rods, guides, etc., longer than the short stroke high speed engine.

A Corliss engine is shown in Figure 41.

A Simple Engine. A simple engine is an engine having one cylinder only. The steam being used in the cylinder pushes the piston, and then escapes through the exhaust.

Double Cylinder Engine. A double cylinder engine is an engine having two steam cylinders, which take the steam direct from the boiler. Each cylinder has its own piston, piston rod, connecting rod and crank. One of the cranks in a double cylinder engine should be set one-quarter of a revolution ahead of the other, which would put one piston near the center of the cylinder when the other one was near the dead center. The object of a double cylinder engine is mainly to prevent the engine from stopping on the dead center. This is of considerable importance in an engine that is started and stopped often. and where it is desired to start slowly with a heavy load, or where it is desired to run an engine very slowly. They are used mainly on locomotives and on hoisting engines, and occasionally on traction engines.

The advantage of having a double cylinder engine is to be able to start the engine up in any part of the stroke by simply opening the throttle-valve.

The objections to the double cylinder engine are that it has more moving parts than the single cylinder engine. If the engine is the same horse power as the simple engine. each cylinder would be one-half as large as the cylinder in the simple engine. We would have, however, more surface exposed to the cold air and there would be more loss of steam from condensation. There is more liable to be loss of steam from leakage of the pistons and slide-valves. Where a traction engine is used for plowing, there is some advantage in having an engine of this type. For ordinary threshing purposes, a double cylinder engine is probably not so desirable, as good results are obtained from the single cylinder engine, and where an engine is equipped with reverse gear, the engine can easily be started without turning the fly wheel to move it off from center, unless it stops exactly on the dead center.

Compound Engines. In order to secure the best results from the power of steam, the steam should be used expansively. This is sometimes accomplished to a fuller extent by passing the steam through two cylinders in place of passing it through one cylinder only, as it does in the simple engine. When expansion takes place in two cylinders the steam passes first into one cylinder and pushes the piston, then passes to another cylinder and pushes another piston, the engine is said to be a compound engine. If the steam passes through three cylinders successively, it is said to be a triple expansion engine. If it passes through four cylinders, it is said to be a quadruple expansion engine.

In a compound engine the cylinders are not of the same size, but each successive cylinder must be larger. The steam from the boiler first enters the smallest cylinder, called the high pressure cylinder. After having pushed the piston to the end of the stroke, it exhausts into the next cylinder, and so on until it has pushed the piston in each cylinder.

When one cylinder is placed at the end of the other and both pistons are connected to the same piston rod, the engine is said to be

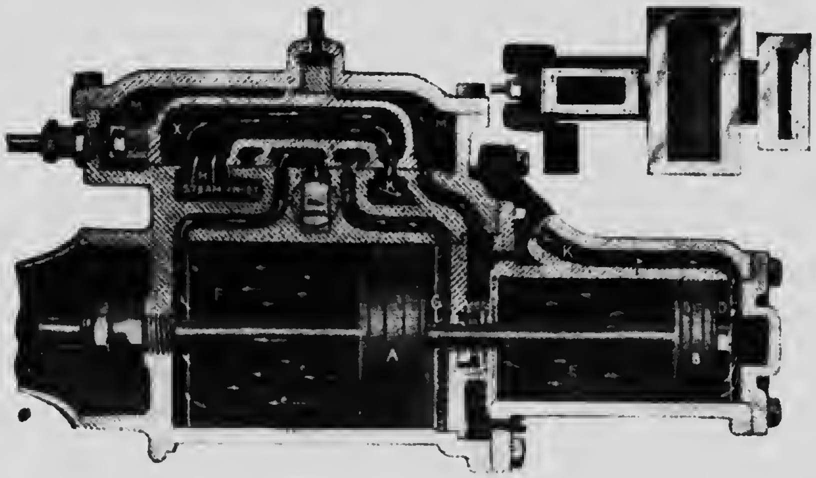


Fig. 42.

a "tandem compound." When the cylinders are placed side by side and each piston and connecting rod attached to a separate crank pin, the engine is said to be a "cross compound." If both piston rods are attached to the same cross-head and one crank pin, the engine is called a "twin compound."

A sectional cut of the Woolf compound engine, which is in quite common use on traction engines, is shown in Figure 42. The movement of the steam to and from the cylinders is controlled entirely with one slide-valve, something similar to the plain "D" slide-valve, except that it is double, and to a certain extent is a balanced slide-valve.

The advantages of a compound engine are that it will work steam more on expansion, and derive more power from a given amount of fuel and water.

The disadvantage of a compound engine is that it has more parts to wear and get out of order than the simple engine. Where fuel and water are important items, it is more economical to have a compound engine. Where fuel is cheap and the water supply convenient, its advantages are not so great.

Condensing Engine. A condensing engine is an engine the exhaust of which is connected with a condenser. An engine which is not connected with a condenser is said to be a non-condensing engine. A non-condensing engine exhausts the steam directly into the atmosphere. In the condensing engine the exhaust pipe is connected with the condenser, which is an arrangement usually supplied with numerous pipes with cold water passing through them. which condenses the exhaust steam. The water from the condensation of the steam is pumped out by means of a pump. By passing cold water through the condenser and condensing the exhaust steam, it would produce a vacuum or a partial vacuum in the condenser. The engine would then be exhausting into a partial vacuum, and we would gain the pressure of the atmosphere, which would be equivalent to adding pressure upon the steam side of the piston. Marine engines are usually condensing engines and also large engines situated close to a water supply, where a quantity of water is available for condensing the exhaust steam. It ordinarily requires about 25 times as much water to condense the exhaust steam, as was required to form the steam applied to the engine. It will be noted that a condensing engine would not be used to advantage on a traction engine. It is thought best, however, to mention condensing engines in order that the engineer may understand something of the different types.

HANDLING A TRACTION ENGINE.

On taking charge of a new traction engine, or taking charge of a traction engine for the first time, the engineer should examine the boiler and engine thoroughly to see that he understands its general construction and operation.

If the engineer is about to start an old boiler or one that has been used before, he should examine the boiler on the inside and see if it is perfectly clean and free from scale. He should also note the general condition of the boiler plate as to whether it is rusted or eaten away so as to be thinner in some parts than in others, or is not of even thickness. If there is any doubt as to the plate being thick enough, he should test it by striking a sharp blow with the ball end of a ball pene hammer. If the plate be thin, it will be possible to dent it with a good blow. If there is any doubt as to its strength, it should be tested by the boiler inspector before firing up. The engineer should see that the engine stands level, leveling it with a small level placed upon the guides for leveling it lengthwise, and with a level placed upon the main shaft for leveling it crosswise. He should trace out all pipes and understand their use, and know exactly what parts they connect, examine the pump and injector in order to be familiar with their working. He should examine the fire box or furnace, also the combustion chamber, and note that no tools or extra parts have been stored in them. If the hand-holes are not in place, he should properly pack them and put them in. Then remove the filling plug on the top of the boiler and fill the boiler with water until it shows about three inches of water over the tubes or crown sheet, filling the boiler with a hose, or by means of pails, pouring the water in through a funnel which is usually provided with the engine. While the boiler is filling with water, he should note the hand-holes to see that they are all tight, If not tight, draw them up with a wrench if possible; if not possible to draw them up tight, it may be necessary to remove them and put on new gasket to make them tight.

He should also examine the gage cocks and glass gage, and note their position in regard to the top of the tubes or crown sheet. He should ascertain their height by filling the boiler until water shows in the glass. and by looking through a hand-hole note how high it is over the tubes or crown sheet. If the water is not over the crown sheet or tubes, he should fill it with water until it is, and note how much water there is in the glass in order to know exactly how much water he is carrying over the tubes or crown sheet. It may be more convenient to level the glass by the use of a spirit level, leveling with a straight edge around from the tubes to the glass.

While the boiler is filling he should clean the tubes, the combustion chamber, the fire box and the ash-pit, removing all soot and ashes. When the boiler is filled with the proper amount of water, it will be safe to start the fire.

Start the fire by first placing in shavings or papers, then kindlings, lighting the fire, and when the kindlings are burning nicely put on the coal or wood. If it be a straw burning engine, the fire may be started directly with the straw, no kindling being necessary. The draft should be opened and where there is no danger from sparks the screen or spark arrester should be removed from the smoke stack to get as strong a draft as possible. In burning coal, when the fire is first started it is well not to put on too thick a fire. A thin fire will burn more freely, as more air can pass through it.

After the fire is started and while the boiler is warming up, go all over the engine, examining the boxes and bolts to see that they are not loose. All bearings should be oiled. Grease cups, oil cups and lubricators filled, and superfluous oil or grease be wiped off with waste or rags. When the fire is burning nicely, it is well to open the upper gage-cock so as to allow any air to escape, and to get an indication as to when steam commences to form. When steam has formed and is coming out of the gage-cock with some force, the gage-cock should be closed, and it should be noted if the steam-gage hand starts to rise. When the steam pressure has risen to 5 or 10 pounds, the blower should be opened to increase the draft and cause the fire to burn more rapidly. When steam pressure has risen to between 40 and 75 pounds on the ordinary traction engine, the safety-valve should be pulled open by hand in order to be sure that it is not stuck in its seat. If any parts upon the engine require packing, such as the piston rod, slide-valve rod, governor valve stem, pump piston, or any of the valve stems, they should be packed while the steam pressure is rising and the engineer is at leisure.

The steam pressure should be raised gradually and the pressure noted upon the steam-gage, until the safety-valve blows off, in order that the engineer may know it is working properly. He should note the pressure at which it blows. It is well to allow the safety-valve to blow off steam each morning when fired up, but it should not be allowed to blow off afterwards unless it is necessary. When the safety-valve blows off it causes a loss of fuel and water on account of the steam and heat escaping.

When steam pressure has risen to nearly the desired point, the blower should be closed. The blower should not be used when the engine is in operation, as all traction engines exhaust through the smoke stack. The exhaust pipe is usually similar in shape to the stack and is turned upward. The end of the exhaust pipe is usually shaped similar to the jet in the injector, and the exhaust steam escaping from it has the same effect as the blower. Some engines are constructed with a variable exhaust, or one in which the size of the opening may be increased or decreased. When the opening is decreased the steam pressure will be increased as it escapes from the nozzle, and will cause a stronger draft. This will, however, cause a back pressure upon the engine. When the opening is increased the pressure of the exhaust steam will be decreased, which relieves the back pressure on the engine, but does not give so strong a draft. The exhaust opening should be left open as wide as possible when steam pressure can be maintained. If, however, the draft is not strong enough to maintain the same pressure, the exhaust nozzle should be closed in order to secure the required draft.

When steam has been raised to nearly the full pressure, the height of the water in the boiler should be noted. The pump or injector should be started in order to see that it is in good working condition, and if the water is not at the proper height in the boiler, it should be left in operation until the required amount of water is obtained.

Starting an Engine. The cylinder cocks of an engine should always be opened when the engine is stopped, and should be left open until after the engine is started and dry steam escapes from them. In starting the engine be sure the cylinder cocks are open. It is well also to open the pet-cock underneath the steam chest, in order to allow part of the condensed steam to escape from the steam chest and not force it through the cylinder. The throttle-valve should be opened slowly in order to admit steam slowly to the cylinder and warm it gradually. Were the throttle-valve opened quickly with a cold cylinder, steam would condense rapidly and form more water than would escape through the cylinder cocks, and there would be danger of breaking out the cylinder head, or at least causing considerable strain upon the bearings of the engine and connections. When the engine has a reverse gear, it is well to move the reverse lever back and forth a few times when steam is first admitted, in order to warm the cylinder at each end. When the cylinder has been thoroughly heated, which can be determined by noting that dry steam issues from the cylinder cocks, the throttle may be opened a little further and the engine allowed to start slowly and gradually brought up to speed.

When the engine is brought up to the required speed and its motion controlled by the governor, the throttle-valve should be opened wide. The cylinder lubricator should be started and if the engine is working under load, the pump or injector should be started in order to maintain the proper amount of water.

When an engine is stopped for an instant only, there is not so much danger from opening the throttle quickly, as the cylinder in that case will be warm. It is always better, however, to start any machinery into motion gradually, as it causes less strain upon all wearing parts. The screen on the smoke stack should be closed when there is any danger from sparks.

While steam is rising in the boiler the fire should be watched carefully and fresh fuel applied as needed. When the steam reaches nearly the required pressure, if it is not desired to start working with the engine at once, the fire should be covered with fresh coal and the draft closed, in order to prevent the steam pressure rising too high. When the engine is working the draft should be left open wide enough to give sufficient draft to the fire.

Running The Engine. While the engine is in operation, such as threshing or whatever work is required from it, the engineer should keep close watch of all moving parts that they do not overheat, and should feel of the bearings occasionally and note their temperature. If they are heating, he should apply oil. If too hot to bear the hand upon them, it is an indication that the engine should be stopped and the bearing loosened slightly. Better to run bearings too loose than too tight. If they are too tight and start heating, the heat will expand the shaft and soon cut it. When the shaft is cut, it is difficult to keep it from wearing or heating.

The engineer should watch his water supply, steam pressure and his fire constantly.

When the engine is running and the engineer has leisure he should make any small repairs that may be made when the engine is in motion. He should see that his supply cart is filled with water and fuel and prepare to move his engine as soon as the separator is stopped.

A good engineer will always be ready to go as soon as the belt is off, and the separator men will not be required to wait for him either before or after moving to a new setting.

Stopping The Engine. In stopping the engine the throttle may be closed quickly without injuring the boiler or engine. The cylinder cocks should always be opened as soon as the throttle-valve is closed. An engineer should make this a fixed habit. As soon as the throttle is closed and the cylinder cocks opened, the engineer should give immediate attention to his fire. If the stop is for a short time with the expectation of starting again quickly, he should add fresh coal and close the draft and damper. If the steam pressure is high and there is not too much water in the boiler, the pump or injector should be started into operation. The lubricator should be shut off and oil cups closed. The engineer should then go carefully over the bearings, feel of them and see that none of them are too hot, and that all bolts and nuts are tight.

If the engine is to stop for some time, such as at night, the pump or injector should be allowed to run until the water is raised to the third gage-cock, or until the boiler has more water in it than is necessary while running. This will allow for any leakage, and will permit of some water being blown out to clean the boiler the next morning. The fire should be allowed to die down before closing down the engine. Before leaving the engine any length of time, the valve at the top and bottom of the glass-gage should be closed, and the glass emptied. This will call the engineer's attention to the fact that the valves are closed. All pipes that are exposed to the cold air, if there is danger of freezing, should be drained, and the lubricator also if it contains water. The engine should be gone over carefully and all grease and superfluous oil wiped off.

The Engine On The Road. When moving the engine on the road the engineer should watch the glass-gage and gage-cocks closely to see that the proper amount of water is maintained. It is usually best to carry the water a little higher while on the road than it is while the engine is at work. There is more or less fluctuation of the water and the tubes or crown sheet may become bare, especially upon hills. Do not, however, carry water high enough to cause priming. The steam pressure should be maintained near the blow-off point. Before going down a hill it is best to put fresh coal on the fire, close the draft and damper. This will prevent too much heat while descending the hill, and no steam is required.

When descending the hill the speed of the engine should not be allowed to increase much above its ordinary speed. When the required speed is reached, steam should be shut off. If this does not check the speed sufficiently, the engine should be reversed, and the air in the cylinder will then act as a cushion retarding the speed. In case this does not check the speed sufficiently, the throttle-valve may be opened a little to admit some steam to the cylinder. The speed of the engine may then be controlled by moving the reverse lever to that point which will admit the proper amount of steam to cushion the piston, and act as a brake upon the engine. As soon as the bottom of the hill is reached the draft and damper should be opened and the fire allowed to burn. If the water is low in the boiler it should be raised a little above where it is ordinarily carried, the object being to have a good steam pressure and sufficient water before ascending the next hill.

Upon approaching a hill the engineer should see that he has a fairly good fire, the usual amount of water, and steam pressure up to near the blowing-off point. The fire should then be checked and not be allowed to burn any more than necessary to give the required steam while ascending the hill. The engine should be controlled by the throttle-valve, and should ascend the hill slowly in order not to use all of the steam quickly at the bottom of the hill. The engineer should watch the steam gage and see that the steam pressure is maintained. If the steam pressure is running down, he should close the throttle a trifle and ascend the hill more slowly. If the steam pressure be allowed to drop to any great extent, there is danger of not having sufficient power to reach the top of the hill.

Do not fire while going up a hill unless absolutely necessary. If the hill be a long one and it is necessary to fire while ascending it, the firing should be done while near the bottom of the hill. Upon reaching the top of the hill the draft and damper may again be opened to increase the fire and raise the steam pressure, and the pump or injector started to raise the water supply. It is not a good plan to allow the pump or injector to run while ascending a short hill. On a long hill it is sometimes necessary to run them in order to maintain sufficient water. Do not run them more than necessary, however, as putting in the cold water will reduce the steam pressure.

The governor belt should not be removed from the governor while the engine is traveling on the road. If it is desired to obtain a higher speed, increase the speed by screwing down the regulating screw on the governor. This will allow the engine to run as fast as it is practical to run it. Running at a higher speed is liable to put more strain upon the bearings etc., than they are able to withstand.

Guiding The Engine. Traction engines are guided while on the road by means of the steering wheel. Turning the top of the steering wheel to the right will turn the engine towards the right. Turning the top of the steering wheel to the left turns the engine to the left. The engine travels in a direction at right angles to the axles, hence when the axles are not parallel it will travel in a circle, the central point of which might be found by extending two imaginary lines, one continuous with the front axle and one continuous with the rear axle, where the two lines cross each other would be the center of the circle upon which the engine would turn. In guiding an engine an engineer should keep his eye on the front wheels and note their position. Do not turn the steering wheel too often or too far, which would have a tendency to wiggle the engine back and forth upon the road.

The steering wheel may be turned more easily when the engine is in motion than when the engine is standing still. When it is desired to change the direction of the front wheels it is well to have the engine moving slowly.

The steering chains, which extend from the front axle back to the steering roller, should be moderately tight, though not tight enough to bind or cause undue friction. If too slack it will be somewhat difficult to guide the engine

Getting Out of a Mud Hole. An engineer should be careful not to get into a mudhole unless absolutely necessary, as the mud being soft the wheels cannot secure a firm hold upon the ground and will have a tendency to turn without propelling the engine. If the wheels turn without propelling the engine the calks upon the wheel will cause it to dig a hole which will be difficult to get out of. As soon as the engine drive wheels slip without propelling the engine, the engine should be stopped, and something put under the wheels, such as rails, posts, straw, boards, brush, or anything that will enable the wheels to get a grip upon the earth. Sometimes a log chain is fastened to some object ahead of the engine and one end thrown under the wheel.

In traveling on a muddy road, or where there is danger of the wheels slipping, it is well to put the mud calks or mud hooks upon them. These are large cast iron calks which may be bolted to the wheels. In getting out of a mudhole the engine should be run slowly, as the engine will not be so liable to lose its footing while traveling slowly.

If stuck in a mudhole while the engine is pulling a separator or a load, an engineer may get out more easily by uncoupling the engine and running ahead with the engine alone until the engine reaches firm footing. Then by means of a rope or wire cable attach to the separator and pull it through the mudhole on to solid ground, then back the engine up and connect to the separator again.

Crossing Bridges. Before crossing a bridge or culvert, the engineer should stop the engine and go ahead to examine the bridge to see if it is strong enough to carry the weight of his engine and separator. If there be any doubt as to the strength of the bridge, it will be better to move the engine around the bridge if possible, or to cover the bridge with heavy planks, placing the planks lengthwise of the road. The weight of the engine will then be distributed over a larger surface of the bridge and the bridge planks will not be so liable to break. It is best to move slowly while crossing a bridge.

In case an engine has broken through a bridge, it is sometimes a difficult matter to get it out of the hole. If the hole is so deep that there is danger of burning the crown sheet or tubes in the boiler, it would be better to draw the fire and pull the engine out by hand, or by means of horses. This could best be accomplished by winding rope several times around the fly wheel, setting the friction gearing, and then by hitching a team to the rope, or having several men pull on it, the fly-wheel will be revolved slowly and the engine gradually lifted out of the hole.

The Friction-Clutch. Nearly all traction engine are now supplied with a friction-clutch, which is an arrangement for throwing the traction gearing into motion and moving the engine. In using the friction-clutch it should not be thrown into gear too suddenly. While the engine would probably be strong enough to stand having the gear thrown in suddenly without breaking any parts, it would cause an extra strain upon the bearings of the engine and in time would be liable to loosen them.

In starting an engine on the road, the engine should be started and the friction-clutch thrown in gradually until the gearing is in motion, when the friction may be set up tight. If traveling over bad roads, the speed of the engine should be slow and controlled with the throttle-valve. When a good piece of road is reached the throttle should be opened wide and the speed regulated by the governor. Friction shoes of the clutch are usually made of wood, and have some arrangement for being set out when worn. In case the friction slips when the friction-clutch lever is thrown clear over, the shoes should be set out a trifle. Be careful not to set them ou too far, as it would cause unnecessary wear if they touched the fly wheel.

A friction-clutch is usually so constructed that by placing a pin (sometimes called the stiff pin) in the fly wheel and friction-clutch bearing, the two will be locked together. When the engine is used for plowing, or when it is used for a long haul on the road, or if the friction-clutch slips, it is sometimes desirable to lock it.

Compensating Gear. A compensating or differential gear is an arrangement by which one drive wheel is permitted to travel faster than the other, when the engine is moving upon a curve. It is located in the drive gearing usually upon the shaft carrying the bull pinions which drive the rear wheels. When the engine is traveling on a straight road, the whole gearing revolves as both drive wheels turn at the same rate of speed. When going around a curve the compensating gear while pulling upon each drive wheel, would allow one wheel to travel faster than the other.

The compensating gear should be so made that it will be possible to lock it solid and cause both drive wheels to revolve at the same speed. This is sometimes necessary, as when

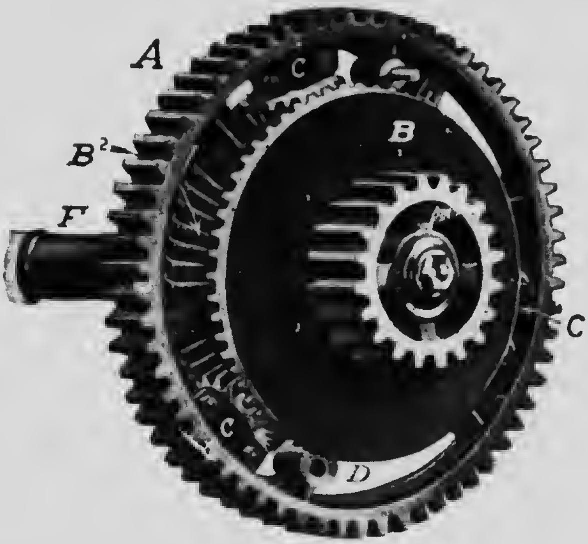


Fig. 43.

one drive wheel strikes a mudhole it is liable to revolve rapidly, and the other drive wheel remain stationary.

One type of compensating gear is shown in Figure 43. The compensating gear receives its motion from another cogwheel meshing into the large outside gear wheel A. When the gear wheel A revolves it carries with it the beveled pinions C. The beveled pinions mesh into the two beveled gears B, each of which carries a bull pinion driving the main wheels. Upon a straight road the beveled pinions C remain stationary. When turning a corner the beveled pinions revolve between the two beveled gears B just enough to allow the wheels to travel without slipping upon the ground or straining axle. A compensating gear may be locked by so placing an iron pin in the outside gear wheel A that it will hold against a projection, H, upon the beveled gear wheel B, in this way locking the two beveled gear wheels B together. A compensating gear should not be locked except where it is absolutely necessary in getting out of a mudhole. As soon as the engine is out of the mudhole, place the locking pin so as not to strike against the projection H. If the compensating gear is locked while turning a corner it causes one drive wheel to slip on the ground, and brings an unnecessary strain upon the bearings.

Reversing Traction Engine While In Motion. When a traction engine is moving on the road and it is desired to reverse the engine, the throttle should first be closed, the engine reversed, and the throttle again opened. This should be done in order that the engine may not be reversed too quickly causing undue strain upon the bearings. Traction engines are usually made strong enough and will stand the strain if reversed while under full speed without closing the throttle. The danger comes, however, in causing the extra strain upon the bearings. If the engine is reversed slowly without closing the throttle less damage will be done, for in reversing the engine the slide-valve closes the steam off from the cylinder and then admits it to the other side, which would be similar to opening and closing the throttle-valve slowly. It is better, however, to get into the habit of first closing the throttle-valve, reversing the engine, and then opening the throttle-valve again slowly.

Setting The Engine. Nearly all threshing outfits are now arranged so the engine pulls the water tank, fuel cart and separator while on the road. The separator is pulled in to the stacks, the engine uncoupled, and the engine must then be turned and placed in position. The engine is usually turned into position by running ahead to the right or left, whichever is most convenient, until at right angles with the separator. The engine is then reversed and backed in the other direction until about the required position. The engine should be backed a little farther than required, if it is not backed into exact line, and then brought up in line with the separator pulley.

When the wind does not blow from either side, the engine should be in exact line with the separator, as shown in Figure 44. The engineer will sight with his eye and bring the side of the fly wheel and the side of the separator pulley in a straight line. The five points A, B, C, D & E should be brought into exact line, A representing the engineers eye, B-C edges of the fly-wheel on the engine, and D-E the edges of the pulley upon the separator. As the pulley upon the separator is small and the separator is a considerable distance from the engineer, it will be difficult for the engineer to see both edges D and E of the pulley. When the engineer is acquainted with the separator, he will locate some point back of the pulley, such as the elevator spout or some point which is in line with the edge of the pulley, to line up with.

If there is a strong side wind, it is well to set the engine a little to one side to allow for the wind, setting the engine towards the

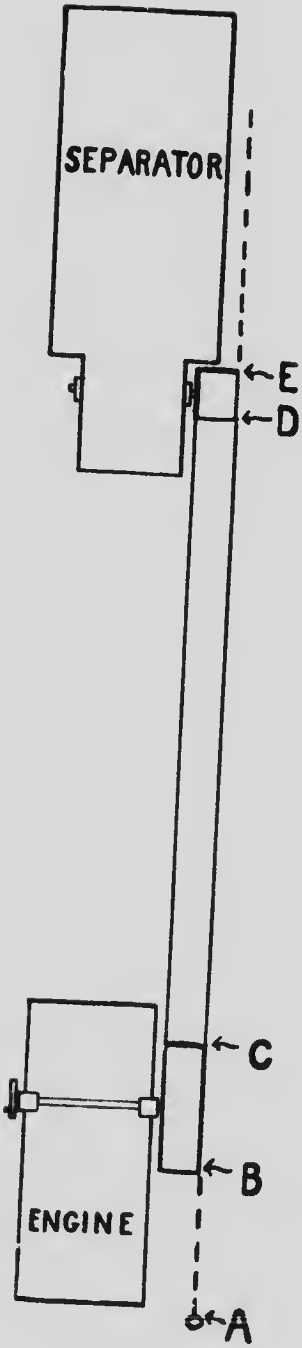


Fig. 44.

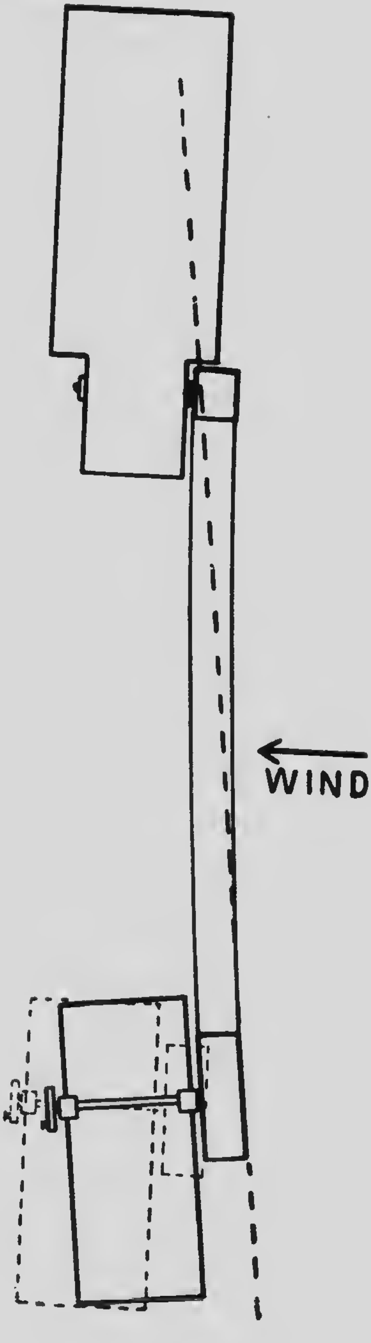


Fig. 45.

wind with its fly wheel turned slightly away from the wind. The wind will tend to carry the belt with it, and the engine should be placed so that the belt will run straight with the fly wheel, also with the separator pulley, as shown in Figure 45. The amount the engine is set over and the direction it is set will depend upon how much the wind blows the belt. The engineer should bear in mind that a belt to run well should run straight toward the pulley it is running on to.

The drive belt should be pulled out and a mark made at the end of the belt where it will lie upon the ground. The mark will serve as an indication as to the place where the shaft of the engine will come. The engine should be brought up nearly to position and in line with the separator pulley. Where the engine has a friction-clutch it is well to run the engine up far enough to put the belt on easily, then by throwing in the friction-clutch a trifle the engine may be backed slightly until the belt is tight enough. The fly wheel on nearly all traction engines turns ahead while threshing and while traveling backwards on the road. By throwing the friction-clutch in slightly while threshing, the belt may be tightened at any time.

A good sized block, or better still a good jack-screw, should be carried to block the drive wheels when threshing. By carrying a short piece of plank and digging a small inclined hole, putting one end of the jack-screw upon the plank and the other against the drive wheel, the screw can be brought up to block the engine securely.

Packing. There should be two kinds of packing with the engine, one for piston rods, valve stems, valve rods, etc., which is called a piston packing; another packing called sheet packing, or gasket, for packing hand-holes, man-holes, under the cover of the steam chest, and places of similar nature.

Piston Packing. Piston packing is any kind of packing that is used for packing piston rods, slide valve rods, and places of similar nature. There are many kinds of piston packing upon the market. The most common packings are hemp packing, asbestos packing, candle wick packing, and patented packing.

Hemp Packing. Hemp packing is made from hemp fiber and looks somewhat like a piece of rope. It is much softer than rope, however. Hemp packing may be used for packing any part of the engine, such as piston rod, valve rod, pump and valve stems. The objection to hemp packing is that it is liable to become hard in the stuffing box and cut the rods more than some other packings. It is not expensive, however, and when properly put in and not allowed to harden in the box good satisfaction may be had from it.

In using hemp packing it should be picked to pieces to take out any lumps or hard pieces. It is then well to oil it with cylinder oil and graphite before putting it in the stuffing box. In putting it in the stuffing box, first dig out all of the old packing which is liable to have become hard, then twist the hemp packing up somewhat like a rope, or, if the stuffing-box is large, braid the packing, until large enough to fill the space between the rod and the side of the box, put a turn around the piston rod and push it down into the stuffing-box. Then put on another turn and push that in, and so on until the stuffing-box is entirely filled. Put in all the packing you can get in. Screw the gland up firmly to force the packing into position. It is well then to slack the gland off to allow the packing to expand. The gland can easily be drawn up by hand tight enough to prevent steam leaking through, which is all that is necessary. If packing is screwed up too tight it is liable to heat the rod and burn the packing. It will also wear the rod and is liable to cut a groove in it lengthwise.

Candle Wick Packing. Candle wick packing is common candle wicking, and may be used for packing valve stems or small parts. The objection to using candle wick packing for piston rods and valve rods is that it is liable to become hard and wear the rods. It is very convenient, however, to have candle wick with the engine, as it is useful in many places.

Asbestos Wick Packing. Asbestos wick packing usually comes in balls and is about the size of the candle wick packing. It is used for packing small valve stems and may be used for packing the piston rod. It is of a softer nature than the hemp or candle wick packing. It gives good satisfaction when used for the governor valve stem or a small stuffing-box. It should not be used, however, for packing the water end of a pump, or a cross-head pump, as the water has a tendency to wash the packing out. It should not be used for packing to hold water pressure.

Patented Packing. There are several patented packings upon the market which give very good satisfaction and are not expensive.

A piston rod which is packed with patented packing will not require packing so often as where hemp, asbestos or candle wick is used. In buying patented packing the size of the packing should always be given. The size of the packing required is the distance between the piston rod and the sides of the stuffing-box, which would be the diameter of the packing required. The sizes are usually in eighths of an inch, such as ¼, ⅜, ½, etc. Where patented packing is used, if packing has been used for some length of time all old packing should be removed and the box filled entirely full of packing. Some kinds go around the piston rod in a continuous coil. Other kinds are cut in short lengths not quite long enough to reach around the rod and put in the stuffing-box so as to break joints. The object of cutting pieces a little short, is that they will hug the rod closer, and are not so liable to leak when the packing wears.

It is a good plan to saturate any kind of packing with cylinder oil and graphite. The graphite will bed into the packing and forms a lubricating surface. The packing will wear longer, and is not so liable to cut or wear the rod.

Worn Piston Rod. In an old engine, or in an engine where the packing has been allowed to become hard, the piston rod often wears smaller in the middle than at the ends. When this occurs, it is difficult to keep the piston rod packed so as to prevent leaking. If the rod is worn to quite an extent it is best to send it to a machine shop and have it turned up true from one end to the other.

Gasket Packing. Gasket packing is sheet packing for use on flat surfaces where there is no wear but where it is desired to make a tight joint. There are several kinds to be had, the most common of which is rubber gasket with cloth insertion. It is also made with wire insertion, which is a little better and not so liable to be blown out.

Gasket packing should not be thicker than required to take up the uneven surface between the parts packed. If the surfaces are uneven or rough a thick packing is necessary, but a thick packing is more liable to be blown out than a thin one., due to more of its surface being exposed to the pressure. Where it is desired to break the joint often, packing should be coated on one side with graphite and cylinder oil, which will prevent its sticking to the plates. In case the plates are nearly true, such as under the cover of a steam chest or cylinder head, sheet lead makes an excellent gasket. It can be used indefinitely, and when well put in will seldom be blown out. The objection to it is that on rough surfaces it has not spring enough to close the opening. Sheet copper also makes a good gasket. Sometimes a copper wire is used.

Asbestos sheet packing may be used for steam but should not be used for water, as it will water-soak and is liable to be blown out. Tar paper is occasionally used for gasket packing on water joints. Heavy manilla paper or an old postal card is sometimes used, where the joints come together fairly close.

On the better class of engines many of the joints are made true and do not require packing of any kind.

Tests for Leaks. A steam engine should be tested occasionally to determine whether there is any leakage of steam in the slide valve or steam piston. Any leakage in either of these parts is wasteful of steam, as the steam is allowed to escape without doing work.

To test the slide valve, place the engine in such position that the high part of the eccentric will be either straight up or straight down from the main shaft. This will place the slide-valve in the center of its travel so as to cover both steam ports equally. Now open the throttle-valve, which will admit steam to the steam chest. If the slide valve leaks, the leaking steam will escape through the cylinder cocks. If the slide-valve leaks to any extent it should be re-faced or re-seated. This would probably necessitate sending it to a machine shop and planing the valve seat and the valve face, and afterwards scraping it to a true surface with a scraper, and testing by means of a true surface plate.

The steam piston may be tested to determine if the piston rings leak by blocking the cross-head and admitting steam to the engine. It is best to test the piston in at least two positions. To test it on the crank end of the cylinder, put the engine on dead center with the piston at the crank end of the cylinder, and turn the engine ahead just a trifle in order to make sure that the slide-valve has opened the steam port. Now block the cross-head by placing a strong hardwood block or an iron bar between the cross-head and the end of the cylinder. Open the throttle-valve, which will admit steam to the cylinder on the crank end. Open the cylinder cock on the head end of the cylinder, and note if steam escapes. If steam escapes to a considerable extent it is an indication that the piston leaks.

To test the piston on the head end of the cylinder, put the engine on dead center with the crank towards the cylinder. Turn the engine slightly ahead to be sure the steam port is open, and block the cross-head by means of a strong hardwood block or an iron bar, placing one end against the cross-head and the other against the end of the guide or the main bearing. Open the throttle-valve, and if steam escapes from the cylinder cock on the crank end of the cylinder, it is an indication that the piston leaks.

The slide-valve should be tested first in order to determine if it leaks. If the slide-valve leaks, this method would not hold good. It might, however, serve as an indication, by noting the amount of steam escaping. It might be that in testing the slide-valve only a small amount of steam escaped, while more escaped while testing the piston. This would indicate that there was a leakage in both the slide-valve and the piston.

It is sometimes found that the piston and valve will leak in one position and will not leak in another. This is due to the fact that the cylinder or valve does not wear evenly. A slight amount of leakage must be expected in making these tests, as frequently there is a slight leakage from the slide-valve and piston, and this leakage would show to a greater extent when the cross-head is blocked than it would when the engine is running. While running the piston and slide-valve are in motion, and probably no large quantity of steam would escape.

If the piston leaks to any extent, it is possible that the engine will require new cylinder rings, or if leaking badly the cylinder should be re-bored. To re-bore the cylinder it is usually necessary to send it to a machine shop, have it put in a lathe and bored out true. This is occasionally done at the engine, but can usually be done in a better manner at the machine shop. When the cylinder is re-bored the piston should be fitted with larger rings. This should make the engine as good as new.

Counter-Bore. On the better class of steam engines the cylinders are counter-bored. Counter-bored means boring the ends of the cylinder a trifle larger than in the center. If a cylinder is not counter-bored, the piston in traveling back and forth in the cylinder is liable to wear a shoulder at each end, as the center part will wear while the ends do not.

By boring the ends of the cylinder a little larger and allowing the piston to travel slightly into the enlarged part, the wearing of the shoulder is prevented.

Pounding. Pounding in an engine is usually due to some part becoming loose or wearing, and if allowed to continue for any length of time will continually become worse. While an engine is more liable to pound in the crank-pin or in the wrist-pin than at any other place, it is no indication that the pounding is always at these points and other points should have careful attention. It is rather difficult at times to locate the exact place where the pounding occurs. This is due to the fact that the sound will travel with the rods. When an engine is pounding it should be gone over very carefully until the loose part is located. Better to allow some pounding than to tighten some bearing too tight and cause heating.

A pound in the crank-pin, wrist-pin or main shaft bearing, may be located by blocking the cross-head on each side, taking hold of the fly wheel and moving it back and forth, watching all of these parts closely and feeling of them with the hand to locate the looseness. The pounding is sometimes caused by the fly wheel being loose, or the governor pulley on the main shaft being loose, looseness in the eccentric straps, or the slide-valve may have too much play endwise on the valve-rod. The valve-rod should never be tightened up tight to the slide-valve. It should have a little play but not enough to cause pounding, just enough to let the valve move back and forth from its seat without binding upon the rod. When pounding occurs go over the engine carefully until the looseness is located. After tightening the loose bearing, watch it closely for some time to see that it does not heat.

An engine will sometimes pound if out of line. When an engine is in line the main shaft should be exactly at right angles to a line running through the center of the cylinder. A line running through the center of the cylinder should cross at exactly right angles a line running through the center of the main shaft. In case it should not do so, the engine would be said to be out of line.

An engine is usually thrown out of line from wear upon the main bearings. Where a heavy belt is pulling upon the fly wheel it will wear the pillow-block on the side on which the heaviest strain comes, and if not adjusted from that side the shaft will soon be out of line. When the engine is out of line the end of the connecting rod connected to the crank-pin has a tendency to pound back and forth on the crank-pin.

To determine if the engine is out of line a fairly good test is to disconnect the connecting rod from the crank-pin, turn the engine on dead center, pull the conecting rod ahead and see if it strikes the crank-pin true. Turn the engine on top quarter, draw the piston ahead, and note if the connecting rod again strikes the crank-pin true. Turn the engine on the other dead center and test with the connecting rod in the same manner. Also test it at the bottom quarter. If the connecting rod strikes the pin true at all positions, it is an indication that the engine is in line.

Many slide-valve engines will pound when steam is shut off from the engine. This is often caused by the slide-valve moving up to and away from its seat. A slide-valve should have some play on the slide-valve rod, and is held to its seat by the steam pressure on the back of it. When steam is shut off from the engine the steam pressure in the cylinder is sometimes higher than it is in the steam chest and will force the slide-valve back against the valve rod. The exhaust port will then perhaps open, and the pressure in the steam chest will force the valve back to its seat. The valve will sometimes move back and forth between the valve rod and its seat for some little time, or until the engine stops. This same rattle is occasionally caused when the engine is working under a very light load, and the governor shuts the pressure off or nearly off from the steam chest. This rattle does no harm at all, and the engineer should not attempt to remedy it. When steam is turned on, however, and the engine is working, this rattling should not occur.

Adjusting Bearings. When a bearing on a steam engine or any machinery is well adjusted, it should run for a considerable length of time without attention other than oiling. Many bearings heat and cause trouble from the fact that they are not properly adjusted, or that the boxes do not contain sufficient liners. All important bearings should be split in halves in order to allow for adjusting for wear. The ideal bearing would be a true hole bored in the box, with a shaft fitting nearly close, leaving only sufficient room for oil to work between the bearing and the box. The oil should be heavy enough to fill this space, and not allow the shaft to move back and forth or pound in the bearing.

In order to allow for wear it is necessary, however, that the box be split. The split box should be held apart, or from bearing too closely upon the shaft, by placing liners between the halves of the box. Liners are usually made from pieces of sheet iron or tin, or sometimes from firm paste board. A sufficient number of liners should be put in to hold the box apart just the proper amount when the bolts are drawn down tight. If an insufficient number of liners are put between the halves of the box, the top part of the box will have a tendency to rub against the shaft, and prevent the box from receiving the proper amount of oil.

When the box wears sufficiently to allow the shaft to move up and down, or pound, some of the liners should be removed, or a thick liner removed and a thinner one put in its place. The bolts should be drawn down tight and the shaft turned to note if it binds. If the shaft binds, another very thin liner should be put in until the box is properly adjusted.

Connecting-Rod Brasses. Means are usually provided in connecting rods for adjusting the brasses or boxes, by the use of a taper pin or an adjustable wedge. The adjustable wedge is so constructed that tightening a bolt on one side of the connecting rod will force the wedge in and tighten the bearing. Tightening a bolt on the opposite side will draw the wedge back and release the bearing. It is common practice in adjusting brasses of this kind to first loosen the bolt which withdraws the wedge, turn the bolt that draws the wedge in, so as to wedge the brasses as tight as possible, then turn the bolt back about $\frac{1}{8}$ to $\frac{1}{4}$ of a turn and tighten the bolt which withdraws the wedge, this will give the required amount of play for oil. Connecting rod brasses are usually constructed so the two halves of the boxes will not come quite close together. When the brasses wear and the halves of the box come together it is common practice to remove considerable from the halves of the box with a file to allow for adjustment.

These brasses are not usually fitted with liners, but connecting rod brasses can be fitted much better, and will run for a much longer time without readjusting, if liners be put between the halves of the brasses. When liners of the proper thickness are placed between the halves of brasses, the wedge may be drawn down solid, which will make the brasses firm at all points except around the crank-pin. This makes the bearing practically solid except the hole for the pin, and the liners hold the brasses away from the pin a sufficient distance to allow a free passage for the oil entirely around the pin, but there is no looseness at any other point. When the brasses are adjusted in this manner there is much less liability of the brasses becoming loose, or of their stopping the flow of oil and heating the crank-pin, and the bearing will run for a much longer time without re-adjustment.

LUBRICATION.

Lubrication. The bearing surface of all parts of the engine will require a lubricant or oil to keep the moving parts from coming too close together and causing friction. Oil acts like small balls constantly rolling between the metallic surfaces and thus reduces the friction.

Two kinds of oil are necessary with steam engines, and in large steam engines three kinds are necessary. One oil, called cylinder oil, is to be used for oiling the slide-valve and steam piston within the cylinder. On a very large engine a heavy oil will be required for the large bearings, such as on the main shaft, and a thinner or lighter oil will be required for the governor, and places of similar nature, where the bearings are light. The cylinder oil must be of such nature as to stand the heat in the steam chest and cylinder. Were engine oil used for this purpose the action of the heat would decompose it, and it would retain none of its lubricating features.

There are various tests for oil, which will determine to some degree the quality of the oil. Many of these tests, however, are difficult to perform and are not used in general practice. For a small engine probably the most satisfactory results are had by buying oil from a reliable dealer, getting a good grade of oil and testing it upon the engine. The amount of cylinder oil used upon the engine will depend upon the size of the engine. A 10 horse power engine would probably require about two to four drops of oil per minute. A 40 horse power engine would probably require about four to six drops per minute. The amount of oil used would also depend upon whether the engine was priming or foaming. When an engine is priming or foaming more oil will be required. A new engine will also require more oil until the slide-valve and cylinder are well polished. After running an engine for, say, one or two weeks, and using a certain number of drops per minute, remove the cylinder head and note the condition of the cylinder on the inside. If the cylinder has a mirror-like appearance on the inside walls, and if upon feeling with the fingers the inside walls appear to be slightly oily, indications are that the oil is good and a sufficient quantity is being used. If the cylinder appears to have considerable oil in it, probably less oil could be used. If the cylinder appears rough and dry, it is an indication either that an insufficient amount of oil is used, or that the oil is of a poor quality. More oil should be used, and if the cylinder still remains rough, it would be advisable to change the brand of oil.

When a brand of oil is found to do the work, it is advisable to keep using that brand, as the engineer will know about how fast to feed it, and it is not a good plan to change the oil upon an engine. It is more economical to pay a good price for cylinder oil and buy a good grade, as a smaller amount will be required to keep the engine in good condition.

Lubricators. In order to introduce the cylinder oil into the steam chest and cylinder, it is necessary that some form of lubricator which will force the oil in against the steam pressure, be used. The most common type of lubricator is the simple oil cup, which is a cup with a tight fitting plug at the top for filling, and a valve at the bottoom for closing when the oil cup is being filled, and for regulating the speed with which the oil is to feed into the engine. This style of lubricator is objectionable in that it is impossible to know just how fast it is feeding oil. Often it will feed oil too rapidly, and the oil cup will become empty before the engineer is aware of it, and the engine is liable to be run for some time before the oil cup is again filled. For this reason it is much better to provide an engine with some sort of a sight feed lubricator.

One style of sight feed lubricator, which is probably in most common use upon stationary engines, is shown in Figure 46. One cut shows the method by which it is attached to the steam pipe, and the other shows a section removed from the body of the lubricator. This is termed a double connection lubricator, having two openings connected with the steam pipe which supplies steam to the engine.

Nearly all sight feed lubricators are caused to work by the weight of the water in the lubricator pipes forcing the oil out of the lubricator. They are so constructed that steam enters a part of the lubricator and condenses or turns to water. The water would have a tendency to run out of the lower opening against the steam pressure. This tendency is due to the weight of the water. The lubricator is so constructed that this water in running out would be required to pass first through the lubricator, and in that manner force the oil out ahead of it. When we say a lubricator is empty, the oil will have passed out of it but the lubricator will be full of water. Before filling the lubricator again with oil, it will be necessary to remove the water.

In Figure 46 it will be noted that the pipe from the upper connection of the lubricator passes down on the inside of the lubricator, and is open near the bottom. It is through this pipe that the water enters the lubricator. As the water enters the lubricator at the bottom through the pipe P it has a tendency to raise the oil to the top of the lubricator. Oil will naturally stay on top of the water. The only way in which the oil can escape from the lubricator is by being taken off from the top of the lubricator through the tube S, carried downward through the regulating valve at the bottom of the sight feed glass, where it is released and passes out through the sight feed glass which is filled with water, or sometimes with glycerine. When the oil is released at the bottom of the sight feed glass, being lighter than the water it will rise to the top of the sight feed glass and flow to the engine through the tube T, which passes directly through the lubricator.

The amount of oil which a lubricator feeds is regulated by the valve at the bottom of the sight feed glass. When the engine is stopped this valve should be closed to stop the lubricator. When the engine is started, it should be opened slightly. This lubricator will need very little attention except in cold weather, when it will be necessary to drain off the water if there is danger of freezing.

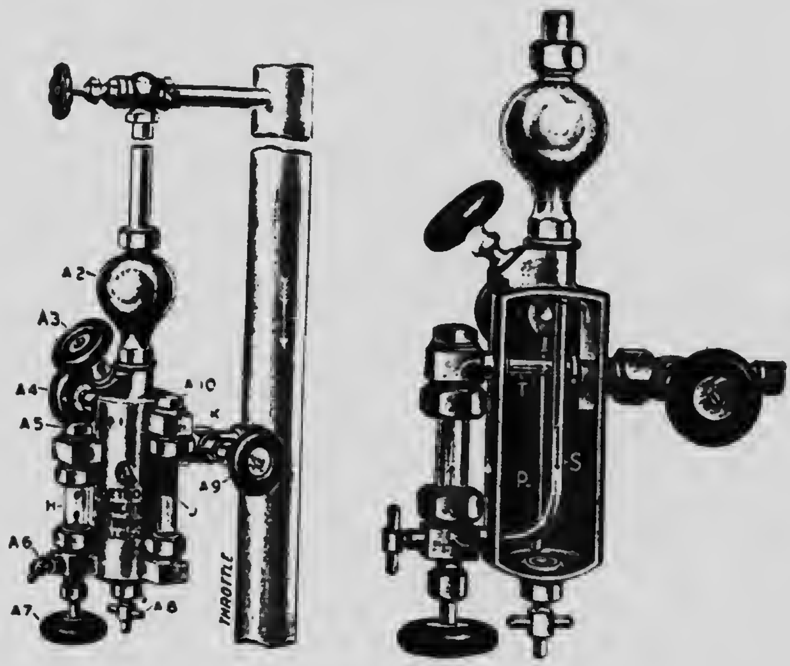


Fig. 46.

To fill the lubricator, first close the valve at the bottom, A7, which will hold the water in the sight feed glass and shut the steam pressure off from the lower connection K. Next close the valve A4. This shuts off the tube

P which admits the water from the condensing chamber A2. It also prevents the steam and water from blowing down through the upper connection when the lubricator is being drained. Next open the drip-cock at the bottom of the lubricator, A8, and remove the filling-plug A3. When the water has all been drained out of the lubricator, close the drip-cock A, fill the lubricator full of oil, and replace the filling-plug A3, open the valve A4 which allows the water from the condensing chamber to pass into the lubricator and puts the pressure upon the oil. Lastly, open the regulating valve A7 until the lubricator feeds the desired number of drops per minute.

In starting a lubricator after filling, always turn the water into the lubricator first before opening the oil regulating valve A7. If the regulating valve A7 be opened first, the steam pressure will pass in through the tube T, and force the water which is in the sight feed glass down through the feed glass and up through the oil tube S, mixing the oil and water in the lubricator and daubing the sight feed glass with dirty oil, and it will be some time before the lubricator will feed properly.

Under ordinary conditions a lubricator does not need to be blown out or the steam allowed to blow through it while filling. This is only necessary when the lubricator is choked up. If the steam be allowed to blow through the lubricator it removes the water from the condensing chamber A2, and the lubricator will not work again until the steam has condensed and filled the condensing chamber with water.

The lubricator shown in Figure 46 has a glass-gage, J, upon one side, simply to indicate the amount of oil there is in the lubricator. As the oil is being used from the lubricator the oil in the glass J will gradually rise to the top. When the oil disappears from sight at the top of the glass, it is time to re-fill the lubricator. It is not a good plan to allow a lubricator to run entirely empty.

The type of lubricator shown in Figure 46 is not in common use upon traction engines. The objection to it is that in cold weather the oil will not be warmed sufficiently by the steam to enable it to feed freely. Where a lubricator is exposed to the cold, as on a traction engine, some form is required in which the steam will pass through a passage in the body of the lubricator, to warm the oil so that it will flow freely.

Another form of lubricator in quite common use is the Swift lubricator, which has a single connection.

In a single connection lubricator it is customary to extend a pipe upward and then downward again into the lubricator, in order to secure sufficient height and pressure from the water to force the oil into the engine.

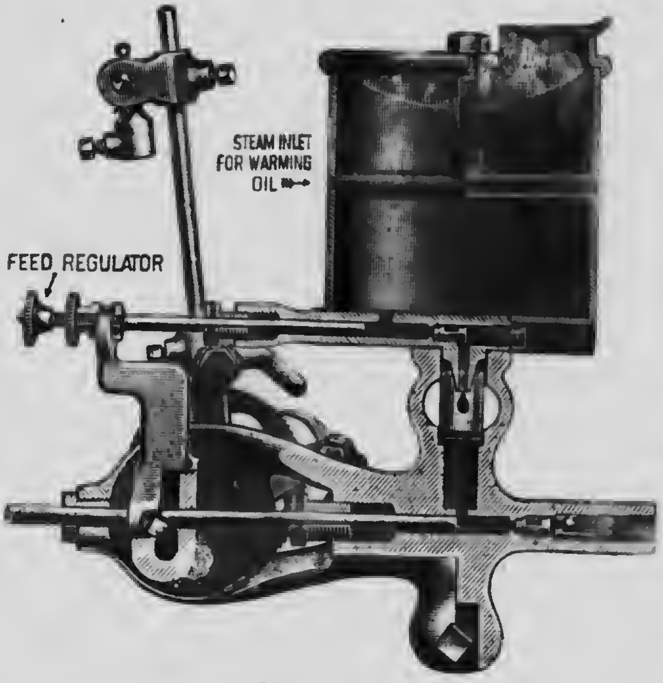


Fig. 47.

Quite a number of engines are now supplied with an oil pump in place of the lubricator, the pump having some connection with the engine so arranged that when the engine is in motion the pump will be in motion and fe the required amount of oil to the engine. When the engine is stopped, the pump will stop.

A section view of one form of oil pump is shown at Figure 47. The amount of oil which the pump feeds to the engine is usually regulated by means of a [illegible] and also by the length of stroke of the [illegible]. Some pumps are placed on top of [illegible] in order to warm the oil. Others are arranged with steam pipe for warming the oil by passing steam through it.

Oil pumps that may be operated by hand are sometimes attached to steam engines and they are desirable where there is liable to be trouble with the lubricator.

Grease Cups. It is quite common practice to lubricate some bearings of machinery with hard oil, which is supplied to the bearings by means of grease cups. Hard oil looks like [illegible] grease or vaseline, and is semi-solid at ordinary temperature. The grease cups are filled with the hard oil, which is fed to the bearing in some cases by screwing down the top of the grease cup occasionally. In other grease cups the oil is forced to the bearing by means of a spring, the amount of the hard oil supplied to the bearing being regulated by an adjusting screw partly closing the passage from the grease cup to the bearing. In case a bearing heats or becomes warmer than the ordinary temperature, the hard oil will melt and lubricate the bearing.

A bearing which is lubricated by means of hard oil will not run quite so freely as a bearing lubricated with liquid oil. But the difference is so small that the convenience of a hard oil cup in many cases offsets it.

Hot Boxes. In case a bearing becomes hot, it is advisable to supply oil and slack the bolts s'ightly if possible. If the bearing has heated to quite an extent, better to oil it with cylinder oil, as the cylinder oil will stand the heat and cool the box better than the common engine oil. In case the box is cut so as to roughen the shaft or the inside of the box, it is advisable to remove the shaft and scrape it or file it smooth. The box should also be scraped to remove any rough projections. Before placing the shaft in the box again, it is we'l to coat the shaft and the inside of the box with a mixture of oil and graphite. The graphite will bed into the uneven surface of the shaft and bearing, and reduce the friction.

Nearly all boxes have, or should have, oil grooves cut in them. An oil groove is simply a passageway leading out in each direction from the oil hole, to serve as a passageway for the oil or grease. The oil groove should not extend clear to the edge of the box, but should stop within about one fourth of an inch from the edge. If extended out to the edge of the box, the oil will be liable to flow out at the end of the bearing.

Wasting Oil. An engineer should use care in oiling bearings, in order to not waste the oil. Bearings should be oiled a little at a time and often. In many cases the oil runs out of the bearing and down the side of the machinery, where it is wasted and gathers dust and dirt. A small quantity of oil is sufficient for a bearing, but it should be oiled often.

Many bearings are now so constructed as to be self-oiling. One of the best methods is to so construct the bearing that an oil chamber will be directly under the central part. Then provide a ring or small chain which will surround the shaft with one side extending down into the oil chamber. As the shaft revolves the chain or ring will revolve and carry up sufficient oil to lubricate the shaft. The superfluous oil will run back into the oil chamber. This method keeps the bearing thoroughly lubricated and prevents wasting of oil, as the oil is used over and over again.

Laying Up the Engine. When an engine is laid up for some time, such as at the end of the season, it should be thoroughly cleaned from oil and grease, the bearings should be oiled to prevent rusting, the cylinder head should be removed, and the cylinder wiped dry on the inside and coated with oil to prevent rusting.The packing should be removed from all stuffing-boxes to prevent rusting of the rods. All bright parts of the engine, such as the piston rod, connecting rod, disk, main shaft, etc., should be coated with a mixture of equal proportions of white lead and tallow melted together. The tallow prevents the white lead from hardening, and the white lead prevents the tallow from being removed too easily. This coating will prevent rusting, and when it is desired to use the engine again, the coating may be easily removed by wetting it freely with kerosene and wiping it off.

Portable Engines. A portable engine is an engine used where it is desired to move the engine frequently, but is not necessary to have the engine self-propelling, the engine being moved by means of horses. The main difference between a traction engine and a portable engine, is that the portable engine does not have the traction gearing.

SIZE OF ENGINE.

The Size of a Steam Engine. The size of a steam engine is often stated by giving the size of the cylinder in inches, the diameter always being stated first. An engine called an 8x10 engine would have a cylinder 8 inches in diameter and a 10-inch stroke. The power obtained from such an engine would depend upon the speed the engine was run and upon the steam pressure carried. A small stationary engine would probably have a piston speed of from 300 to 600 feet per minute. An engine with a short stroke would usually run a greater number of revolutions per minute.

Actual Horse Power. The actual horse power of an engine is the power which an engine has for driving machinery, aside from what is consumed in overcoming its own friction. This is called the actual horse power, and is usually marked A. H. P.

Indicated Horse Power. The indicated horse power of an engine is the power required to drive the engine itself, as well as to drive other machinery, and would be the total power of the engine. The engine will not do quite as much work as shown by the indicator on account of the power consumed in driving itself. Indicated horse power is marked I. H. P.

Brake Horse Power. The brake power of an engine is the power which an engine will give to a brake applied to the fly wheel. This would not include the power required to drive the engine itself. The brake horse power would be marked B. H. P. If a steam engine were to develop 8 brake horse power or actual horse power, and it requires 2 horse power to drive the engine itself, it would be called a 10 indicated horse power and 8 actual or brake horse power engine.

Estimated Horse Power of an Engine. The horse power or size of an engine may be estimated when the size of the cylinder, the length of the stroke, the number of revolutions which the engine runs per minute, and the average steam pressure on the piston during its full stroke, are known. The average steam pressure upon the piston during its full stroke can best be determined by a steam indicator. Where a steam engine indicator cannot be used, it is common practice in slide-valve engines to estimate the average pressure at one-half of the boiler pressure. This is about what would be obtained when the engine is working to its full capacity.

The average steam pressure upon the piston during its full stroke is called the mean effective pressure, and is usually marked M. E. P.

To find the horse power of an engine, multiply the M. E. P. on the piston in pounds per square inch by the area of the piston in square inches, to obtain the total pressure on the piston. Multiply twice the number of revolutions per minute by the length of the stroke, and reduce it to feet to obtain the feet of the piston per minute. Multiply the total pressure on the piston by the piston speed to obtain the total work done per minute. Divide this last product by 33,000 (the number of foot pounds in one horse power); the quotient will be the theoretical horse power of the engine.

In determining the horse power of an engine in this manner, some allowance should be made for the amount of power consumed by the engine itself while running.

In calculating the area of the piston, allowance should be made for the space on one side which is occupied by the piston rod. To obtain the average area upon which the steam acts, deduct one-half of the area of the piston-rod.

In figuring the horse power of an engine with a steam engine indicator, the only object of the indicator is to find the average pressure upon the piston during its full stroke. It is often used not only to find what horse power the engine is capable of developing, but also to determine the amount of power required to drive any machinery. In figuring the horse power the rule would be exactly the same as the above rule, except that in place of taking one-half of the boiler pressure, we would take the pressure recorded by the indicator.

Increasing the Power of an Engine. It will be noted that the power of an engine may be increased in two ways, one of which is to increase the steam pressure. If the boiler be strong enough to stand an increased pressure, the power of the engine may be increased by carrying the pressure higher. This would give a higher average pressure upon the piston. The power of the engine will increase in direct ratio as the steam pressure increases. Doubling the steam pressure upon the engine would double the power of the engine, providing the steam pressure were maintained.

The other manner of increasing the power of the engine would be to increase the piston speed, or the number of revolutions which the engine runs per minute. If the boiler be large enough to maintain the steam pressure, when the speed of the engine is increased the power of the engine will increase in direct ratio with the increase of the speed. Doubling the speed of the engine would double the power of the engine, if the steam pressure were maintained.

STEAM ENGINE INDICATOR.

Steam Engine Indicator. The steam engine indicator is an instrument for recording the steam pressure at all points of the stroke of the piston. It is seldom used upon traction engines or engines of small size. For the

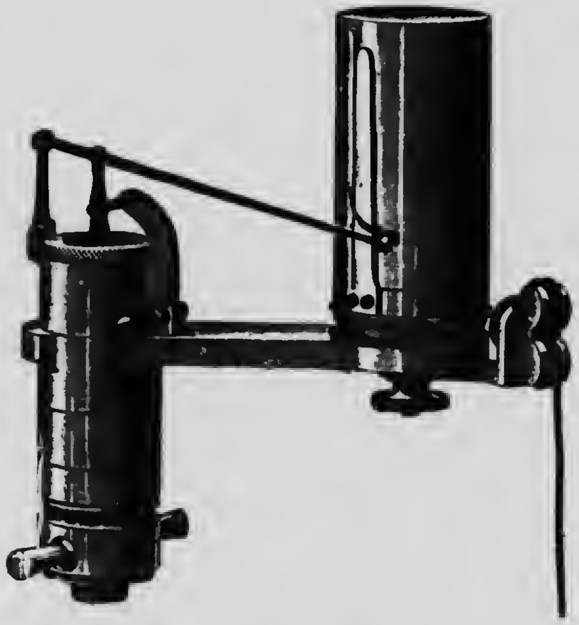


Fig. 48.

larger engines which use a considerable amount of steam, it is a very valuable instrument. The three main objects for which the indicator can be used are, first, to serve as a guide for setting the valves of an engine;

second, to determine the power required to drive any machines or machinery; third, to determine, in connection with a feed water test, the economy with which an engine works.

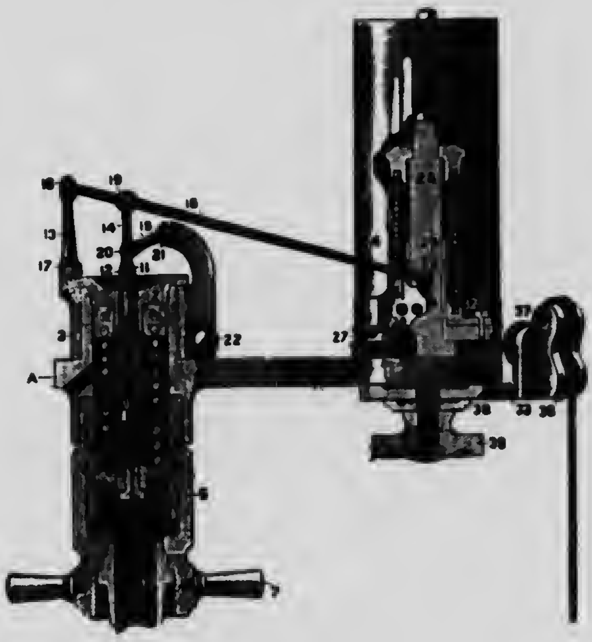


Fig. 49.

There are several different makes of indicators on the market, all of which are made practically upon the same principle. Figure 48 is a cut of the Crosby indicator. Figure 49 is a cut of the same indicator in section, showing the steam piston and spring, also the spring controlling the drum. The instrument consists of a cylinder 4, containing the piston 8, with a piston rod extending to the top of the indicator and connected by means of a link to the pencil arm 16. The cylinder also contains a spring, one end of which is attached to the upper part of the indicator, and the other end to the indicator piston. The indicator is attached to the steam engine cylinder by the union 7. The steam is turned on and off from the indicator by the use of a valve. Upon the smaller engines this is often what is termed a three-way valve. The indicator would be attached directly to the valve and two pipes would lead from the valve, one to each end of the cylinder. On large engines the indicator is attached at one end of the cylinder at a time in order to do away with the long pipes, and secure more accurate results. When the indicator valve is opened to one end of the cylinder, steam is admitted to the indicator cylinder, causing the piston 8, to rise according to the pressure in the engine. As the piston rises, it raises the pencil arm. At the end of the pencil arm is a lead pencil adjusted to bear tightly upon a paper carried upon the indicator drum. The indicator is so constructed that the pencil will rise in a vertical direction. The indicator spring is so constructed that one pound of steam pressure on the piston will raise the pencil a certain amount. If the spring it what is termed a 40-pound spring, 40 pounds pressure per square inch upon the piston would raise the pencil one inch. 80 pounds would raise the pencil 2 inches. 100 pounds pressure would raise the pencil 2½ inches.

The pressure upon the indicator piston can be determined by measuring the height the pencil point rises, as the pencil will rise and fall according to the pressure in the cylinder. The upper drum 24 is so constructed that a piece of paper about 3x6 inches may be put around it and held firmly by clips. The upper drum is caused to revolve by attaching a cord to a reducing motion from the cross-head of the engine. Were the cord attached directly to the cross-head on a large engine, a very large drum would be required. This is avoided by means of a reducing motion which will give the cord a shorter travel than the cross-head. When the engine makes a stroke in one direction the cord turns the drum. The drum contains a spring which turns the drum in the other direction when the cross-head is returning. It will be noted then that the drum turns back and forth exactly in accordance with the movement of the piston in the engine cylinder.

When the sheet of paper, or "card" as it is named, is stretched upon the drum, and the pencil brought to bear upon it, the instrument traces upon the paper a line termed the "indicator diagram." Since the motion of the drum is made to coincide with the motion of the piston of the engine, and the height to which the pencil rises varies according to the steam pressure in the cylinder, the indicator diagram presents a record of the pressure of steam in the engine cylinder at every point of the stroke. The shape of figure traced upon the indicator card depends altogether on the manner in which the steam pressure acts in the cylinder. If the steam pressure be admitted at the beginning and exhaust at the end of the stroke, the admission continuing from one end to the other, the shape of the diagram is nearly rectangular. If the admission continue through only a part of the stroke, the diagram would be similar to that shown in Figure 50, which is given to illustrate the essential features of the indicator diagram. This diagram is about the same as would be obtained from a slide-valve engine cutting off at about one-quarter stroke.

The diagram shows that the admission of steam commences at A and ends at D. The cut-off commences at C and becomes complete at D. Expansion occurs from D to E. The release of the exhaust begins at E and continues to the point H. The compression of the exhaust steam commences at G and ends at the admission point A. The line A-B is called the

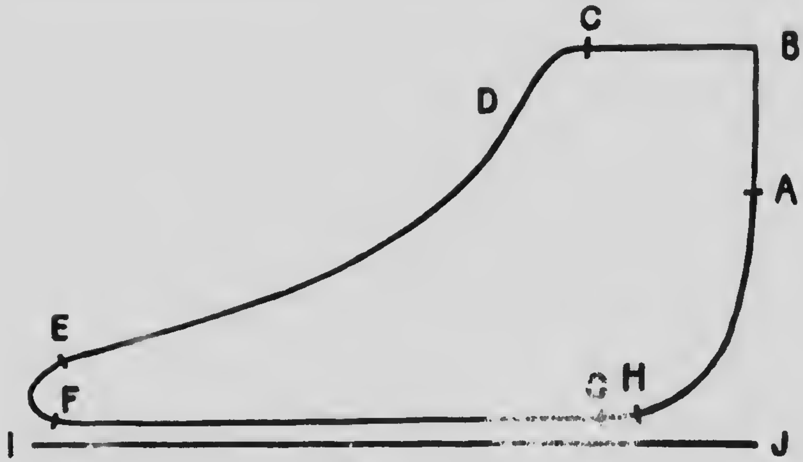


Fig. 50.

admission line; B-C the steam line; D-E the expansion line; F-G the exhaust or back pressure line, (or in case of a condensing engine, the vacuum line); H-A is the compression line, and I-J the atmospheric line.

The atmospheric line I-J is a straight line taken when steam is not admitted to the indicator. The piston in the indicator would then be acted upon only by the pressure of the atmosphere. The point of the pencil would remain stationary, and the straight line I-J would represent the pressure of the atmosphere. In an non-condensing engine the back pressure line F-G would be above the atmospheric line. In a condensing engine the line F-G would be below the atmospheric line. The distance below would correspond to the vacuum in the condenser.

The diagram shown represents the work the piston was doing upon one end of the cylinder only. Another diagram, which is often taken upon the same card, should be taken from the other end of the cylinder. If both diagrams are of the same shape and size, it is an indication that the engine is dong the same amount of work on each end.

The pressure at the points of cut-off, release and compression, are the heights of the various points above the atmospheric line measured and compared with the scale of the spring used in the indicator.

The diagram shows the pressure of the steam at every point of the stroke. The power is computed from the average amount of this pressure, which is independent of the adjustment of the valves, the form of the diagram, or of any condition upon which economy depends. The diagram gives what is termed the indicated power of the engine, which is the power exerted by the steam. The indicated power consists of the net power delivered, and in addition the power consumed in propelling the engine itself.

In this way an indicator is valuable for measuring the amount of power transmitted to a machine or set of the machines that the engine is employed to drive. The manner of measuring the power consists in indicating the engine first with the machine in motion, and then with the driving belt thrown off. The difference in the amount of power developed in two cases would be the amount of power required to drive the machine.

The average pressure shown by the indicator diagram is sometimes measured with a special instrument called the "planimeter," which is a recording instrument made in such a manner that by tracing the outlines of the indicator diagram with one of its points, the average pressure may be read upon a scale. When the planimeter is not used, the average pressure may be found by drawing a line at each end of the diagram at right angles to the atmospheric line, dividing the space between the two vertical lines into, say, ten spaces, measuring the height of the diagram in the center of each of these spaces, from the bottom of the diagram to the top. Adding the height of the ten spaces and dividing it by ten, will give the average height of space.

Multiplying the average height of space by the pressure of the spring, would give the average steam pressure, or mean effective pressure, per square inch, from one end of the cylinder to the other.

The Prony Brake. — The brake horse power of an engine is the actual power which the engine will develop aside from the power required to drive the engine itself, and is the power it would be capable of supplying to a machine. The most common method of determining the power of the engine in actual operation is by means of the "Prony" brake. The Prony brake may be used for testing the power developed by a steam engine, gas engine, electric motor, or any machine from which power is obtained.

Figure 51 is a cut of a Prony brake as it is usually applied to the flywheel of an engine. It consists of two blocks of wood fitted to the pulley of the engine, and is so arranged that by tightening up the bolts they may be made to grip the pulley more firmly. One of the blocks has an extension arm which rests upon a pair of scales, or, if the lever be turned on the opposite side from that shown, it may be weighted with weights, or, what is still better, held by means of a spring balance. When the engine is in motion and the screws are tightened on the blocks, the arm tends to be carried around with the pulley. With the end

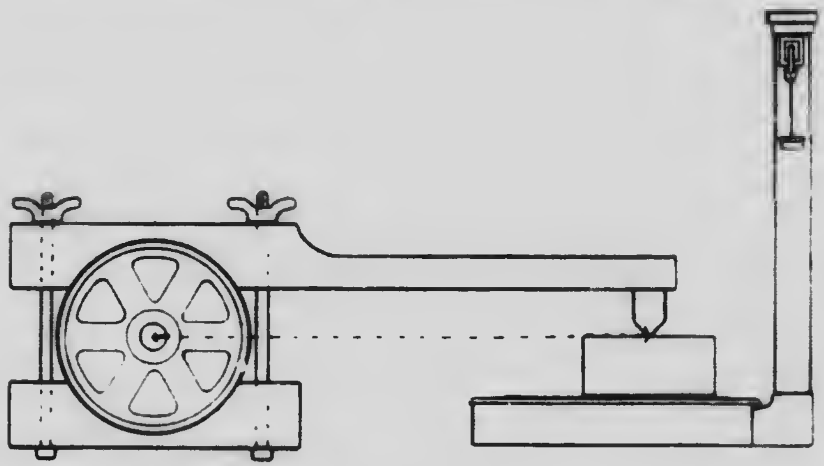


Fig. 51.

of the arm resting upon the scales this is prevented, and the pressure with which the arm presses down upon the scales may be weighed upon the scales. The engine is started and the bolts drawn up until the friction of the brake causes the engine to work to its full capacity.

In applying the Prony brake to a large pulley, it is quite common to attach a number of blocks to a belt or iron band surrounding the pulley, having the ends attached to the arm resting upon the scales.

The blocks are kept cool by means of a stream of water running upon them, or in some cases they are greased, or oiled. The running water is better, however.

It is evident that when the engine is in motion the pressure which is obtained at the end of the arm would be the same as would be obtained from a pulley having a radius equal to the distance from the center of the shaft to the point of the arm resting upon the scales. Multiplying the circumference, then, of a pulley having a radius equal to the length of the arm in feet, by the number of pounds shown upon the scales, by the number of revolutions per minute, would give the foot pounds of work which the engine was doing. By dividing this product by 33000 (the number of foot pounds in one horse power), the horse power of the engine is obtained.

It will be noted that the size of the pulley is immaterial, for the length of arm is taken from the center of the pulley to the point of bearing upon the scales.

Example: Revolutions per minute, 200. Pressure given on the scales, 30 pounds. Distance from center of pulley to point of bearing of arm upon the scales, 3 feet. To find the horse power developed:

3 feet, Length of arm.
2

6 feet, Diameter of pulley having radius
3.1416 equal to length of arm.

18.8496 feet, Circumference of pulley having radius equal to length of arm.
18.8496
200 Revolutions per minute.

3769.9200 Feet per minute.
30 lbs. Pressure on scales.

113097.6000 Foot pounds.

33000) 113097.6 (3.42+Horse Power.
99000

140976
132000

89760
66000

In calculating the brake power of an engine, the figuring may be simplified considerably by making the length of the arm 5 feet and 3 inches, in which case we would multiply the weight on the scales by the number of revolutions per minute, and divide by 1000, which would give the horse power.

If the arm upon the brake be very heavy, it should be counter-balanced, in order that the weigth of the arm may not be considered as power given by the engine.

SPEED OF PULLEYS.

Speed of Pulleys and Gearing. In calculating the speed of pulleys for running shafting or machinery, it is not necessary to find their circumference. Pulleys are spoken of in reference to their diameter. The diameter of pulleys commonly runs in even inches, and in calculating them, where the calculations come under or over a full inch, the fraction is either thrown off or added to, as the case may be, in order to allow for slipping. Belts will slip or creep a trifle on pulleys. The driven pulley should be a trifle smaller than it figures. The driving pulley should be a trifle larger than it figures, to allow for slipping. In calculating the speed of gear wheels or chain sprocket wheels, multiply or divide by the number of teeth in the wheels.

The pulley upon the engine, or the one which is doing the work, is called the driving pulley. The pulley upon the shafting, or the one that is being driven, is called the driven pulley.

Rule 1. To find the number of revolutions of driven pulley, when the diameter of the driving pulley and its speed are given:—

Multiply the diameter of the driving pulley by its number of revolutions per minute, and divide the product by the diameter of the driven pulley. The quotient will be the speed of the driven pulley.

Example:

Diameter of driving pulley—30 inches.

Revolutions per minute—200.

Diameter of driven pulley—15 inches.

What is the speed of the driven pulley?

30 multiplied by 200 equals 6000.

6000 divided by 15 equals 400, speed of driven pulley.

Rule 2. To find the diameter required for driven pulley, when its number of revolutions and the diameter and number of revolutions of the driving pulley, are given:—

Multiply the diameter of the driving pulley by its number of revolutions, and divide the product by the number of revolutions the driven pulley is to make.

Example:

Diameter of driving pulley—30 inches.

Revoltions of driving pulley per minute—200.

Speed required of driven pulley—400 revolutions.

What should be the diameter of the driven pulley?

30 multiplied by 200 equals 6000.

6000 divided by 400 equals 15 inches, diameter of driven pulley.

Rule 3. To find the number of revolutions of driving pulley, when its diameter and the diameter and speed of driven pulley are given:—

Multiply the diameter of driven pulley by its revolutions, and divide the product by the diameter of driving pulley. The quotient will be the speed required of driving pulley.

Example,

Diameter of driving pulley—30 inches.

Diameter of driven pulley—15 inches.

Speed of driven pulley —400 revolutions.

What is the speed of the driving pulley?

400 multiplied by 15 equals 6000.

6000 divided by 30 equals 200, required speed of driving pulley.

Rule 4. To find diameter of driving pulley, when its speed and the speed of driven pulley and its number of revoulutions per minute, are given:—

Multiply the diameter of the driven pulley by its number of revoltuions per minute. Divide the product by the number of revolutions of the driving pulley. The quotient will be the diameter of the driving pulley required.

Example:

Speed of driving pulley—200 revolutions per minute.

Diameter of driven pulley—15 inches.

Speed of driven pulley—400 revolutions.

What should be the diameter of the driving pulley?

400 multiplied by 15 equals 6000.

6000 divided by 200 equals 30, size of required driving pulley.

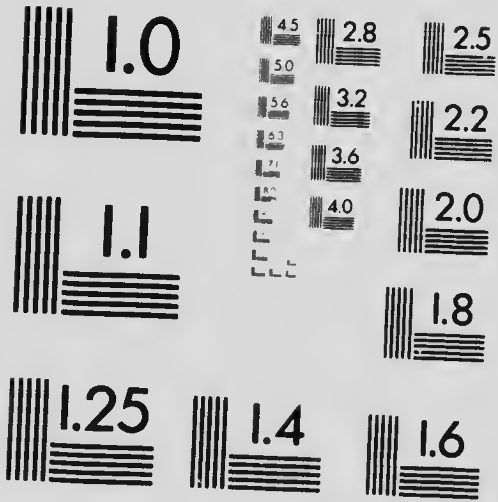
BELT LACING.

Lacing Belts. In order to get the best service from a belt, it should be cut the proper length and well laced. The belt should be tight enough to prevent slipping, but not tight enough to cause heating of the bearings. The proper tension of a belt can best be learned by experience.

In putting on a leather belt it should be placed with the "hair" side or hard side next the pulley. After a belt has been run for a short time and is in good condition, this side will carry the most power without slipping. The belt will also last longer when run with this side next the pulley. Upon examining a leather belt it will be noted that the hair side is much more firm than the flesh side. If a belt be put on with the flesh side next the pulley the hair side will be obliged to stand the pulling strain. As the belt becomes older or harder, this pulling strain will crack the belt on the hard side. The strain must then be carried by the flesh side alone, which will have a tendency to stretch and the belt become loose. If a belt be run with the hard side next the pulley, the flesh side will stretch

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



a trifle and the strain will be distributed through the entire thickness of the belt. Leather belts should be placed so as to run off from the laps and not on to the laps. This will prevent the belt from turning up at the ends of the splices.

There are many patent belt fastenings upon the market, but probably the most satisfactory for all around work is the ordinary belt lace. If the lacing be well made, the belt should run for a considerable length of time without attention. One difficulty is that lacings are often put in hurredly and are not properly done.

The ends of the belt should be cut perfectly square across. The holes should be punched exactly opposite each other in the two ends. In punching holes in a leather belt it is well to use an oval punch, the longer diameter of the punch being parallel with the belt, so as to cut off as little of the belt as possible. In a rubber or Gandy belt, the holes should be made with an awl, which will separate the canvas in the belt without cuttting it.

For the best method of lacing there should be two rows of holes. It is usually better to put one more hole in the row next to the end, than in the second row. The size of lace to use will depend upon the size of the belt. If a light belt, the lace should be one-quarter of an inch wide, or less. With medium belts, 3/8 inch lace should be used. For heavy belt use ½ inch lace.

Lace leather may be bought either in the hide or in bunches of 100 feet. 100 feet of lace would be pieces sufficient to reach 100 feet if they were laid end to end. Each piece is usually about four feet in length. Where much lace is used it is better to buy the hide, as in this way any desired width of lace may be cut.

In lacing belts always keep the lace straight on the side of the belt that runs next the pulley, crossing the lace on the outside of the belt. Always start lacing in the center of the belt and at the center of the lace. Lace out and back with each end of the lace. This will bring the end of the lace back to the center of the belt. By placing the ends of lace through small holes punched a short distance back from the other holes, so the lace will draw through firmly, there will be no need of tying it. Simply cut off the lace about one-half inch from the hole. In making the lacing, the belt should be held so the sides of the belt will be straight with each other.

After the lacing is made, it is a good plan to lay the belt on a block and with a hammer or mallet pound it down a little to flatten the lace where it passes through the holes and prevent jumping when the splice passs over the pulleys.

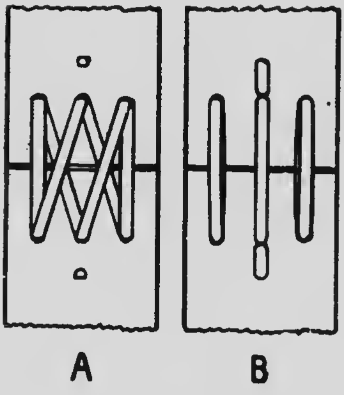


Fig. 52.

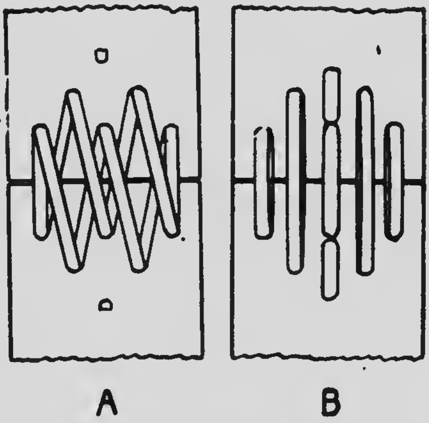
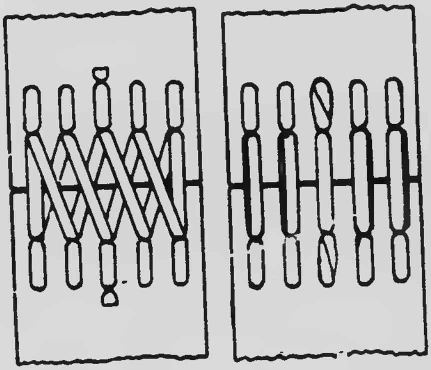


Fig. 53.

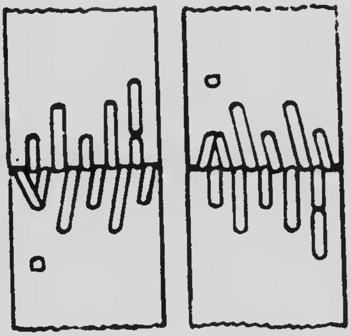
Figure 52 shows a lacing for a small belt pulling a medium load. This is a good lacing where too much strain is not put upon the belt. A shows the flesh side of the belt, or the side away from the pulley. B shows the hair side, or the side running next the pulley.

Figure 53 shows a good lacing for a belt somewhat larger and heavier, and where much more work is required.

Figure 54 shows a lacing for a heavy belt doing heavy work. While this lacing is a little more complicated to make, it will stand more strain and will probably run with less pounding than the other lacings. The central part of the splice has two thicknesses of the lace, while the part farthest away from the joint of the belt has only one thickness. In this lacing the one thickness strikes the pulley first and then the double thickness, which allows the splice to mount the pulley without pounding to a great extent.



A B
Fig. 54.



A B
Fig. 55.

Figure 55 is the "hinge" lacing, and is frequently used on a belt running rapidly over a small pulley. This belt is laced the same as a baseball cover is sewed. In making this lacing the ends of the belt should be bevelled off a trifle so as not to wear the lace. In making this lacing it is necessary that the ends of the lace come at the sides of the belt, as the lace passes only once through each hole. This is in order to get as thin a lacing as possible and prevent pounding as it passes over the pulley.

Belts are sometimes made endless. This is accomplished by trimming the ends of the belt down so as to lap and cementing them together with a belt cement. A belt that is made endless will run much better and quieter than where lacing is used. The objection to an endless belt is that it requires some time to make the joint, and it is more difficult to take off when it becomes slack, as the joint would have to be opened and re-cemented.

A leather belt should be oiled with neats foot oil to keep it in good working condition. It should not be soaked full of the oil, as it would be liable to stretch, but just enough to keep it pliable and prevent cracking. It is not a good plan to apply rosin, or anything of similar nature, to a belt to prevent slipping. A belt should be wide enough and tight enough to do the work required of it without slipping. Rosin applied to a belt has a tendency to make it hard, and will shorten its life.

BABBITTING.

Babbitting Boxes. Babbitt metal is a metal which may be melted at a low temperature, and is used for lining boxes in order to make the boxes fit the bearings properly and prevent friction. Babbitt metal is named after the inventor. The genuine babbitt is composed of 1 pound copper, 2 pounds antimony and 22 pounds tin. The metals are melted together and form the babbitt metal. Babbitt metal can be obtained at prices form eight to fifty cents per pound. The cheaper grades contain more or less lead, and sometimes zinc.

Boxes which require babbitting are made after two general patterns. One is the solid box which does not allow of adjustment for wear. The other is the split box, in which wear may be taken up by removing the liners and tightening the box.

To babbitt a solid box, first chip or melt out all of the old babbitt and clean out the retaining holes. If the box is a difficult one to babbitt, it would be best to heat the box in order to prevent it cooling the babbitt too quickly, the babbitt will also run more freely in the warm box. It may be warmed by placing it in the fire before babbitting it, or by holding a hot iron against it. Have the shaft clean and place it in position in the center of the box, and see that the shaft is level and parallel with the other shafts. Block it into proper position.

In the solid box it is necessary to allow for some play upon the shaft. If the babbitt is poured directly on the shaft, when it cools it will be too tight to allow for oil. To allow for this, wrap about one thickness of writing paper around the shaft and tie it with cord wrapped a few times around it, being careful not to allow the cord to extend to the outside of the box. After the babbitt is poured the space occupied by the string will form grooves for oil.

Make collars from paste-board that will fit the shaft and place them close against the ends of the box, stopping any small opening with putty or with clay mixed with water to form a stiff mud. Melt the babbitt in a ladle or shovel, being careful not to get it too hot. As soon as the babbitt is melted so as to flow freely, stir it with a clean pine stick. If the metal is hot enough to burn or char the stick, it is ready to pour. If the babbitt is allowed to become too hot it is liable to spoil it. Pour the babbitt through the oil hole of the box until the box is full. Remove the putty and work the box back and forth to remove it from shaft. Take out the paper and cord, drill out the oil hole, and the box will be ready for use. If no drill is at hand, sometimes the oil hole is retained by placing a wooden plug in it which reaches down to the shaft, and pouring the babbitt metal in through a hole formed at one end of the box having a funnel made from putty around it.

In babbitting a split box, fit the lower half of the box with the shaft in position, blocking the shaft in the position required. Place liners upon the box which will touch the shaft the full length, except two or three notches on the side next the shaft to allow the babbitt to reach the lower half. Bolt the top part of the box in position, stop the ends, and pour the babbitt the same as in the solid box. After the babbitt is poured, drive a cold chisel between the halves of the box to break the babbitt off in the notches of the liners. Trim and slightly bevel the edges of the babbittt where the halves of the box come together. It is a good plan to cut oil grooves extending from the oil hole to near the end of each box. These grooves are usually cut in the form of a letter X crossing at the oil hole. Cut with a round nose or diamond point chisel.

The split box may also be babbitted by placing the lower half in position and babbitting the lower half first, pouring the metal directly on the shaft where it will run down on each side. When the lower half is full, place the liners in position extending them close to the shaft. Bolt the upper half of the box in position and babbitt it. The liners will prevent the babbitt from running together. The upper half may be easily removed.

It is not necessary to use paper around the shaft when babbitting the split box. The necessary space for oil may be obtained by placing an extra liner on each side of the box and scraping the edges where the box comes together to relieve it.

Before pouring babbitt always make sure that the box is perfectly dry. Any moisture is liable to form steam and blow the babbitt out. Sometimes a small lump of rosin is added to the babbitt to prevent it blowing out.

SOLDERING.

Soldering. A soldering iron is made from copper, the medium size weighing 1½ to 2 pounds. In order to work properly a soldering iron must be "tinned," in order that the solder will stick to it and follow the iron. There are two common ways of tinning the soldering iron, one by the use of rosin and the other by the use of sal-ammoniac. The sal-ammoniac is the better, as it cleans the iron more quickly.

To tin a soldering iron, heat the iron a little below red heat, file it bright on the end to remove all dirt and have it perfectly clean. Rub it on a block of sal-ammoniac and hold a piece of solder against it. The solder will melt and stick to the iron giving it a bright appearance when it is tinned. If the pulverized sal-ammoniac is used, pour some of it on a piece of sheet iron or tin and rub the hot iron and solder into it. Rosin may be used in the same manner but will not work so well as the sal-ammoniac.

In heating a soldering iron, be careful not to get quite red-hot. When heated to a red-hot temperature the solder will melt off from it and it will require re-tinning.

To solder bright tin rosin is commonly used for a flux to cause the metal to flow freely. On rusty tinware, iron, brass, copper, or nearly all metals, better results may be had by using a soldering fluid. One of the most common fluid is muriatic acid diluted with zinc.

To prepare this fluid, place some of the acid in a bottle and then put in it some pieces of zinc metal. The acid will dissolve the zinc until its strength is weakened. Put in a little more zinc than the acid will dissolve. The fluid will then be ready for use.

When soldering care should be taken to keep the soldering iron clean, have it properly tinned, and keep it at the proper temperature. The surface to be soldered should be dry, and scraped or filed perfectly clean. Put on some of the fluid by means of a small brush or stick, and melt the solder into it with the soldering iron. Move the iron along so as to melt the solder freely and allow it to flow into the opening, and smooth up all edges. Do not, however, hold the hot iron too long in one place, as the solder will melt and fall away from the iron.

QUESTIONS AND ANSWERS.

The following is a list of questions and answers some of which are usually asked by boiler inspectors when giving an engineer an examination for a license. The questions asked by a boiler inspector depends to a considerable extent upon what kind and size of boiler the engineer desires to operate, also upon the engineer's experience and personal appearance. The boiler inspector will often ask questions which he does not expect the applicant will be able to answer. He asks the question simply to bring out an expression from the applicant, and learn whether he is honest and reliable. An applicant is usually questioned as to his age, the amount of experience which he has had, in firing and in operating an engine or machinery of any kind. Also as to what class and size of machinery he desires to operate. If the applicant has had experience with engines and boilers, he should be able to state the kind and size of boiler and engine, also state the general design of the engine and boiler. The applicant should not attempt to answer questions which he does not understand. He should be perfectly free in his explanations, and not attempt to explain anything which he does not understand.

Q. What is steam?

A. Steam is a vapor given off from water when heated to the boiling point.

Q. What is the boiling point of water?

A. The boiling point of water depends upon the pressure. In an open kettle, at the sea level, water boils at a temperature of 212 degrees Fahrenheit. If confined in a closed boiler, the boiling temperature will rise when the steam pressure rises. If a vacuum be produced the water will boil at less than 212 degrees, the boiling point depending on the vacuum secured.

Q. What is the temperature of steam at 100 pounds gage pressure?

A. 337 degrees Fahrenheit.

Q. How much more space will water occupy when turned into steam than it occupied as water?

A. The space occupied by the water when turned into steam will depend upon the pressure. At the pressure of the atmosphere it will occupy about 1,700 times as much space. At 100 pounds gage pressure it will occupy about 240 times as much space.

Q. How should the glass gage be set on a boiler?

A. The glass gage should be set so that the bottom of the glass is level with or just a trifle higher than the crown sheet or top row of tubes in the boiler.

Q. Are glass gages always properly set on boilers?

A. No. Often they are placed too high or too low.

Q. How could you tell if a gage was properly set?

A. By leveling it with a spirit level, or by removing the handhole and measuring the amount of water over the tubes or crown sheet, and comparing it with the amount shown in the glass gage.

Q. How should the gage-cocks be set

A. The lowest gage-cock should be set about one inch above the crown sheet or top row of tubes. The middle gage-cock should be about four to six inches above the crown sheet or top row of tubes, the distance depending somewhat upon the size of the boiler. A large boiler should have the gage-cocks a little higher.

Q. How much water would you carry over the tubes or crown sheet?

A. From four to six inches, depending upon the size of the boiler. A large size boiler should have a little more water than one of a smaller size.

Q. What harm would it do to carry more water?

A. Carrying more water would not leave sufficient steam room in the boiler, and the boiler would be liable to foam or prime. Water would be carried over with the steam into the engine. This would be wastful of fuel, as cold water must be pumped in to maintain the water level, and the engine would not run as well as it would with dry steam.

Q. What harm would it do to carry less water?

A. Carrying less water would be dangerous in case the pump or injector should stop working, the water level would become too low and there would be danger of burning the tubes or the crown sheet.

Q. How often would you clean the tubes on a boiler?

A. The tubes should be cleaned with a scraper as often as necessary to keep them perfectly clean. The frequency of cleaning them will depend upon the amount of fuel used and to what extent the boiler is used. They should be cleaned in the morning before firing up, at least.

Q. How would you manage a boiler in regard to keeping it clean?

A. The frequency of cleaning a boiler will depend upon the amount of water that is used and to what extent the boiler is used. Under usual conditions the boiler should be blown out a little every day. It is a good plan before stopping after a day's run to pump in more water than is required while running. The next morning after the fire is started, and from 10 to 40 pounds pressure has been raised, open the blow-off valve and blow the water down to the proper level. If the water is very muddy, it is a good plan to blow it out a little after dinner, before starting up. After the boiler has been run for some length of time, usually from one to three weeks, the water should all be turned out, and the boiler opened and thoroughly washed inside. The boiler should not be blown out under steam pressure. The best time to blow it out is when the steam pressure has just gone down and the water is hot. Open the blow-off valve, let all the water run out, remove the handholes and manholes, and wash the boiler with a hose if pressure can be had. The boiler should also be scraped with a scraper consisting of an elliptical shaped piece of iron shaped to fit the side of the boiler and fastened to a rod for a handle.

Q. Is it always necessary to use a boiler compound?

A. No. In many cases boiler compounds would be of no benefit whatever, especially where the water is soft and contains only substances which form a mud, and do not turn into a hard scale.

Q. Under what conditions is a boiler compound necessary?

A. A boiler compound is necessary when the water is such as to form a hard scale on the shell and tubes of the boiler, and it is not possible to keep it from forming by washing the boiler frequently and scraping it with an iron scraper.

Q. Will boiler compound make the water perfectly pure?

A. No. All that a boiler compound can do is to change the scale-forming substance in the water so as to prevent it forming a hard scale, but it will remain in the boiler in the form of a soft mud which must be removed by blowing out and washing the boiler frequently.

Q. How low is it safe to allow the water to become in the boiler?

A. A boiler is safe, and more water may be admitted, as long as there is water over the tubes or crown sheet. It is always best, however, not to allow the water to become lower than one inch above the tubes and crown sheet.

Q. What should be done in case the water becomes as low as the tubes or crown sheet.

A. When the water becomes as low as the tubes or crown sheet, the fire should be pulled out and the boiler allowed to cool down before admitting more water.

Q. What precautions should be taken with the safety valve?

A. The safety valve should be opened every morning when about 40 pounds steam pressure has been raised, in order to see that it is in good working order and not stuck to its seat.

Q. Give several causes for a boiler feed pump refusing to work?

A. Leaks in the suction pipe; pump plunger worn; sticks, etc., getting under the pump valves or check valve; pump not properly packed; too high a lift; the water too hot; pump being air bound; suction pipe being clogged up; discharge pipe between the pump and the boiler may be filled with scale.

Q. Give several causes for an injector refusing to work.

A. Leaks in the suction pipe; sticks, etc., being drawn into the injector partly closing the openings; too high a lift; water too hot; not sufficient steam pressure; leaking check valve; the injector scaled up; discharge pipe between injector and boiler may be scaled up.

Q. What are the usual causes of leaking boiler tubes?

A. Boiler tubes are liable to leak when the flue doors are open and allow cold air to strike them. The tubes being of thinner material than the boiler shell will cool quicker, and in cooling contract more than the shell of the boiler, causing a strain at the tube ends. When the water is allowed to become below the tubes in the boiler, they will become overheated and are liable to leak.

Q. How would you stop boiler tubes from leaking?

A. Small leaks may usually be stopped by the use of a beading tool, turning the ends of the tube down against the tube sheet. If the tubes leak badly, they should be expanded with a tube expander and then beaded down with the beading tool.

Q. What causes "foaming" in a boiler?

A. "Foaming" is usually caused by the boiler being dirty or the water being impure. It is more liable to occur when the water is high in the boiler and the engine is working hard.

Q. How would you prevent "foaming?"

A. "Foaming" may be prevented by keeping the boiler clean and using as pure water as is possible to get. Carry the steam pressure high, and do not carry more water than is necessary to be safe.

Q. What parts would you examine closely on taking charge of a steam boiler and engine?

A. The boiler should be examined closely inside and out to determine whether it is clean, also if the boiler material is in good condition, the boiler not rusted, pitted, bagged or blistered. Also notice the ends of the tubes and see that the bead is not burned or rusted off. Trace out all pipes. See how the glass-gage and gage-cocks are set comparing them with the top side of the top row of tubes, or with the crown sheet. Examine the pipe between the pump or injector and boiler to be sure it is not scaled up. See that all valves are packed and are in good working condition. If the boiler is set in brickwork, see that all cracks or openings which would admit air, except through the ashpit doors, are carefully closed.

Q. What is a simple engine?

A. A simple engine is an engine that uses steam once only.

Q. What is a compound engine

A. A compound engine is an engine using the steam more than once, passing it first into a small or high pressure cylinder and exhausting from the high pressure cylinder into one or more other cylinders.

Q. What is a condensing engine?

A. A condensing engine is an engine that exhausts into a condenser, which is a contrivance for condensing the exhaust steam, thereby gaining part of the pressure of the atmosphere.

Q. What is "lead" on an engine?

A. "Lead" on an engine is the amount of opening which the slide valve allows into the steam port when the engine is on dead center.

Q. How would you give an engine more lead?

A. In a simple slide-valve engine give the engine more lead by turning the eccentric ahead on the shaft, or the direction in which the engine was running.

Q. If an engine had more lead on one end than on the other how would you make it even?

A. The lead must be made even by moving the slide-valve on the rod, or by adjusting the eccentric rod, one-half of the difference between the lead on each end.

Q. If an engine is given more lead, what effect will it have on the point of cut-off, compression and exhaust of the engine?

A. If an engine is given more lead the point of cut-off, the compression and opening of the exhaust port will all take place earlier in the stroke.

Q. What would you do if the water got out of sight in your glass-gage?

A. If the bottom of the glass-gage was set level with the top of the tubes or crown sheet, pull out the fire and allow the boiler to cool down before adding water. The engine should be allowed to run in order to relieve the pressure.

Q. What would you do in case the water was becoming low in the boiler?

A. When water got down to within one inch of the tubes or crown sheet, and it was not possible to get water in immediately, the fire should be banked with fresh coal or ashes.

If a wood or straw fire, it should be allowed to die out. The engine should be stopped in order to hold what water there is in the boiler. As soon as water can be obtained and the pump or injector started, it will be safe to admit more water.

Q. How would you regulate the amount of water a cross-head pump puts into the boiler?

A. The amount of water which a cross-head pump will put into a boiler is regulated by a valve on the suction pipe.

Q. How would you reverse a simple slide-valve engine?

A. A simple slide-valve engine is reversed by placing the engine on dead center, turning the eccentric about one-third way around on the shaft in the direction the engine was running, or until it has the same amount of lead on the same end it had running in the other direction.

Q. Is the piston of an engine in the center of the cylinder when the crank pin stands at the top or bottom quarter?

A. No. When the crank is at top or bottom quarter the piston will be a little more than half way towards the crank end of the cylinder. The distance it would be past the center would depend upon the length of the crank and connecting rod.

Q. Is the area of the piston the same on each side?

A. No. The side of the piston towards the crank has less area on account of the space occupied by the piston rod. In estimating horse power one-half the area of the piston rod is deducted from the area of the piston. This is done for the reason that one-half the work on the piston is done on the end where the rod does not take up part of the piston area and one-half is done on the end where the piston rod occupies part of the area.

Q. What would be the horse power of a simple slide-valve engine having a cylinder 6x9 inches running 225 revolutions per minute, carrying 100 pounds steam pressure on the boiler. Diameter of the piston rod 1¼ inches.

A. 6 times 6 equals 36. 36 times .7854 equals 28.2744 inches (area of piston).

28.2744 minus .6135 (half the area of the piston rod) equals 27.6639 inches(actual area of the piston).

27.6639 times 50 (half of hoiler pressure) equals 1383.195 (total average pressure on piston).

9 inches (length of stroke) times 2 equals 18 inches of travel of piston with each revolution.

225 times 18 equals 4050 inches.

4050 inches divided by 12 equals 337.5 feet, travel of piston per minute.

1383.195 times 337.5 equals 466,828 foot pounds.

466,828 divided by 33,000 equals 14.1 horse power.

Q. State by steps how you would put an engine on dead center.

A. First, Turn the engine about ⅛ of a turn above dead center.

Second, Make a mark across the cross-head and guide.

Third, With one end of a tram placed upon a permanent mark on the engine frame, make a mark on the fly-wheel or disk with the other end of the tram.

Fourth, Turn the engine below dead center until the mark on the cross-head is brought in line with the mark on the guide.

Fifth, With one end of the tram placed in the same permanent mark on the engine frame, make another mark on the engine fly-wheel or disk.

Sixth, Measure on the fly-wheel or disk and find a point half way between the two marks made with the tram.

Seventh, Turn the engine so as to bring this center point on the engine fly-wheel or disk even with the point of the tram. The engine will then be on dead center.

Eighth, Find the opposite dead center by repeating the operation on the other end, or by measuring around one-half way on the fly-wheel or disk.

Q. State by steps how you would proceed to set a slide valve in a simple slide- valve engine.

A. First. Put the engine on dead center.

Second. Turn the eccentric one-fourth of a turn ahead of the crank.

Third. Place the slide-valve in the center of its travel so as to cover both steam ports equally, and fasten it to the valve rod.

Fourth. Turn the eccentric ahead the direction the engine is to run until 1/32 of an inch lead is obtained on the same end of the cylinder that the piston is on. Fasten the eccentric to the shaft.

Fifth. Turn the engine on the other dead center to see if you have the same amount of lead on the other end. If the lead is equal on both ends the valve will be set.

Sixth. If there is more lead on one end than on the other, make the lead even by moving the slide valve on the rod, or adjusting the length of the eccentric rod, until it has the same lead at both ends.

Seventh. If the valve has too much lead on both ends, but the lead is equal, give less lead by turning the eccentric back. If there is not enough lead turn the eccentric ahead.

RULES AND INFORMATION.

To find the area of a triangle, multiply the base by the altitude and take half the product.

To find the area of a rectangle, multiply the length by the breadth.

To find the circumference of a circle multiply the diameter by 3.1416.

To find the diameter of a circle, divide the circumference by 3.1416.

To find the area of a circle, multiply the square of the diameter by .7854.

To find the cubic contents of a cylinder, multiply the area of the base by the height.

To find the surface of a sphere, multiply the square of the diameter by 3.1416.

To find the cubic contents of a sphere, multiply the cube of the diameter by .5236.

To find the cubic contents of any irregular solid, fill a vessel to the brim with water; sink the body in the water, catching the water which is displaced and measuring it.

A gallon of water weighs 10 pounds and contains 277.27384 cubic inches.

A cubic foot of water contains 6¼ gallons, 1,728 cubic inches, and weighs 62½ pounds.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

The standard horse power is 33,000 pounds raised one foot in one minute.

The standard horse power for steam boilers is the evaporation of 30 pounds of water per hour from a feed water temperature of 100 degrees F. into steam at 70 pounds gage pressure.

TABLES.

Cubic Feet In a Ton of Coal.

Hard coal, one ton occupies ......40—43
Soft coal, one ton occupies ....43—48

Dry Measure.

2 pints	=	1 quart
8 quarts	=	1 peck
4 pecks	=	1 bushel

Liquid Measure.

4 gills	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon
31½ gallons	=	1 barrel

Long Measure.

12 inches	=	1 foot
3 feet	=	1 yard
16½ feet	=	1 rod
320 rods	=	1 mile

Square Measure.

144 sq. inches	=	1 sq. foot
9 sq. feet	=	1 sq. yard
272¼ sq. feet	=	1 sq. rod
160 sq. rods	=	1 acre
640 acres	=	1 sq. mile

Cubic Measure.

1728 cubic inches	= 1 cubic foot
27 cubic feet	= 1 cubic yard
128 cubic feet	= 1 cord (wood)
277.27384 cubic inches	= 1 gallon
2150.42 cubic inches	= 1 bushel

Melting Point of Substances.

Substance.	Deg. F.	Substance.	Deg. F.
Mercury	—39	Antimony	815
Ice	32	Bronze	1692
Tallow	92	Silver	1740
Sulphur	239	Gold	1975
Tin 1 Lead 1	408	Copper	2000
Tin	446	Cast Iron	2075
Bismuth	505	Steel	2480
Lead	613	Wrought Iron	2822
Zinc	780	Brass	1850

Weight of a Cubic Foot of Substances.

Substance.	Wt. lbs.	Substance.	Wt. lbs.
Aluminum	162	Hickory, dry,	53
Brass	504	Ice	58.7
Brick	125	Iron, cast,	450
Cement, (Portland)	90	Lead	711
Coal, hard, heaped bushel, loose	80	Mercury at 32° F.	849
Coal, soft, heaped bushel, loose,	76	Oak, dry,	50
Earth, common loam, dry	76	Salt	45
Gold	1204	Sand, dry,	100
		Snow	15—50
		Steel	490
		Water	62.5

Standard Bolt Threads.

Diameter.	No. Threads per Inch.	Diameter.	No. Threads per Inch.
1/4 inch	20	9/16 inch	12
5/16 "	18	5/8 "	11
3/8 "	16	3/4 "	10
7/16 "	14	7/8 "	9
1/2 "	13	1 "	8

Temperature of Fire Corresponding to its Appearance.

Appearance	Temp. Fah.	Appearance	Temp Fah.
Red, just visible	997°	Orange, deep.	2010°
Red, dull	1290°	Orange, clear	2190°
Red, cherry dull	1470°	White heat	2370°
Red, cherry full	1650°	White, bright	2550°
Red, cherry clear	1830°	White, dazzling	2730°

Composition of Metals and Alloys.

	Copper	Tin	Zinc	Lead	Antimony	Melt'g Point
Babbitt	4	88	....	....	8	....
Brass, common	85	....	15	....	....	1850°
Bronze	80	18	2	....	....	....
Fusible plug	....	100	....	....	....	446°
Plumbers' solder	....	33	....	67	....	450°
Tinners' solder	....	50	..	50	....	408°

Proper Size of Pop Safety Valves, Crosby's.

	Inches					
Diameter of Valve	1	1¼	1½	2	2½	3
Capacity in Horsepower	10	20	30	50	80	100

Wrought Iron Pipe.

Table of Standard Dimensions, as Manufactured by the National Tube Works Company.

Diameter			Transverse Area		Nominal Weight per Foot	Number of Threads per Inch
Nominal Internal	Actual Internal	Actual External	Actual Internal	Actual External		
Inches	Inches	Inches	Sq. Ins.	Sq. Ins.	Lbs.	
1/8	.27	.405	.0573	.129	.241	27
1/4	.364	.54	.1041	.229	.42	18
3/8	.494	.675	.1917	.358	.559	14
1/2	.623	.84	.3048	.554	.837	14
3/4	.824	1.05	.7333	.866	1.115	11½
1	1.048	1.315	.8626	1.358	1.668	11½
1¼	1.38	1.66	1.496	2.164	2.244	11½
1½	1.611	1.9	2.038	2.835	2.678	11½
2	2.067	2.375	3.356	4.43	3.609	8
3	3.067	3.5	7.388	9.621	7.536	8
4	4.026	4.5	12.73	15.904	10.665	8

Capacity of Circular Cisterns and Tanks in Barrels of 31½ Gallons.

Depth in Feet	Diameter in Feet													
	5	6	7	8	9	10	11	12	13	14	15	16	17	18
5	23	34	46	60	75	93	113	134	158	183	210	[illegible]	260	302
6	28	40	55	72	91	112	135	161	189	219	252	886	323	263
7	33	47	64	85	106	131	158	188	221	260	294	334	377	423
8	37	54	73	95	121	149	180	215	252	292	336	382	431	483
9	42	60	82	107	136	168	203	242	284	329	378	430	485	544
10	47	67	91	119	151	186	226	269	315	365	420	477	539	604
11	51	74	100	131	166	205	248	295	347	402	462	525	592	665
12	56	81	110	143	181	224	271	322	378	439	503	573	647	725
13	61	87	119	155	196	242	293	349	410	475	545	621	701	785
14	65	94	128	167	211	261	316	376	441	512	587	668	755	846
15	70	91	137	179	227	280	338	403	473	548	629	716	808	906
16	75	107	146	191	242	298	361	440	504	585	571	764	862	967
17	79	114	155	203	257	317	384	457	536	621	713	812	916	1027
18	84	121	164	215	272	336	406	483	567	658	755	859	970	1088
19	89	128	174	227	287	354	429	510	599	694	797	907	1024	1148
20	93	134	183	239	302	373	451	537	630	731	839	955	1078	1208

LEGAL WEIGHTS AND MEASURES.

The legal weights in Canada are the Imperial pound avoirdupois and the Imperial bushel. By Act 42 Vict., 1879, Chap. 16 (amended by Chap. 30, Acts of 1898) it is provided: That in contracts for sale and delivery of any of the undermentioned articles the bushel shall be determined by weighing, unless the bushel measure be specially agreed upon; the weight equivalent to a bushel being as follows:

Kind of Grain.	Weight per bushel.	Kind of Grain.	Weight per bushel.
Wheat	60 lbs.	Castor Beans	[illegible] lbs.
Indian Corn	56 lbs.	Potatoes	60 lbs.
Rye	56 lbs.	Turnips	60 lbs.
Pease	60 lbs.	Carrots	60 lbs.
Barley	48 lbs.	Parsnips	60 lbs.
Malt	36 lbs.	Beets	60 lbs.
Ooats	34 lbs.	Onions	50 lbs.
Beans	60 lbs.	Bituminous Coal	70 lbs.
Flaxseed	56 lbs.	Clover Seed	60 lbs.
Hemp	44 lbs.	Timothy	48 lbs.
Blue Grass Seed	14 lbs.	Buckwheat	48 lbs.
Lime	80 lbs.		

By the same Act the British hundredweight of 112 pounds and the ton of 2240 pounds were abolished, and the hundredweight was declared to be 100 pounds, and the ton of 2000 pounds avoirdupois, thus assimilating the weights of Canada and the United States.

The legal measures in Canada are the Imperial yard and the Imperial gallon of 277.27384 cubic inches. The Imperial gallon is equal to 4.54174 litres, while the wine gallon used in the United States is equal to 3.735 litres.

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