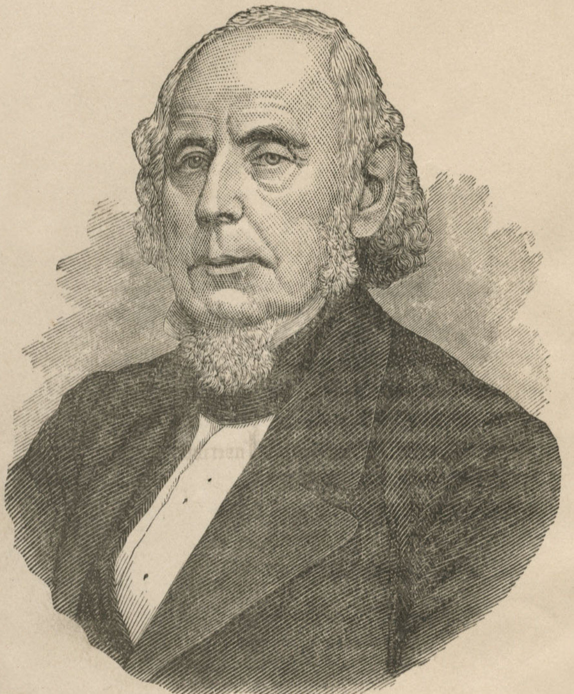


M. W. BALDWIN.

A name as familiar as household words wherever, on the American Continent, the Locomotive has penetrated.

TO

H. W. HOOK, Esq.,

THIS VOLUME

Is Respectfully Inscribed.

HAND-BOOK

OF THE

LOCOMOTIVE,

INCLUDING THE

CONSTRUCTION, RUNNING, AND MANAGEMENT
OF LOCOMOTIVE ENGINES AND BOILERS.

With Illustrations.

BY

STEPHEN ROPER, ENGINEER,
Author of
"Roper's Catechism of High-Pressure or Non-Condensing Steam-Engines," "Roper's Hand-Book of Steam Fire-Engines," "Roper's Hand-Book of Land and Marine Engines," "Roper's Handy-Book for Engineers," "Roper's Improvements in Steam-Engines," "Roper's Use and Abuse of the Steam-Boiler," "Roper's Questions and Answers for Engineers," etc.

Thirteenth Edition, Revised.

PHILADELPHIA:
EDWARD MEEKS.
1888.

Entered according to Act of Congress, in the year 1874, by
STEPHEN ROPER,
in the Offic of the Librarian of Congress, at Washington.

INTRODUCTION.

THIS book was not written because the writer believed there was any scarcity of books on the locomotive in the market, but because he was aware that most of the works on that subject were written by authors who did not fully comprehend the wants of those for whom they were intended; for what use are long mathematical problems or entangling formulas to those who do not fully understand them? Comparatively few engineers are good mathematicians; and perhaps it is just as well that they are not, because it is well known that nature rarely combines high mathematical talent with tact, practical observation, and energy—qualifications so essential to the successful engineer.

It has been heretofore a common custom with men who wrote books on the locomotive to embody in them lengthy descriptions of stationary and marine engines; but the writer of this work has avoided everything not directly connected with the locomotive engine, because he believes that a book, in a certain sense, is like a clock — any complication of its machinery has a tendency to impair its usefulness and effect its reliability. If men having charge of locomotive engines desire to inform themselves on other branches of engineering, they can do so at a very small expenditure of time and money.

The writer has had an experience of over thirty years with all classes of steam-engines and boilers, and in the preparation of this little book his aim has been to convey his meaning by means of plain language, with familiar and practical illustrations for the instruction of those who are intrusted with the care and management of locomotive engines and boilers. The range of subjects comprehends everything directly connected with the locomotive engine and boiler. To most of the articles, tables have been appended and examples introduced to make the subjects treated upon more forcible and distinct.

In that part of the work devoted to the "Theory of the Locomotive," the writer has endeavored to call the attention of the young engineer to the study of the constituent elements of water, air, heat, combustion, steam, etc., so that in after years he may be able to determine with accuracy whether he is deriving the greatest amount of practical advantage from the several quantities of impulsive power those elements may be capable of supplying.

The author cheerfully admits that the work possesses no literary merit, and he disclaims any attempt at fine writing, but he hopes that the work will be found to possess at least the merit of being plain and correct; and, in short, he trusts that it will be found what he has endeavored to make it — a PRACTICAL "HAND-BOOK OF THE LOCOMOTIVE."

CONTENTS.

For a full reference to the Contents in detail, see Index, page 319.

	PAGE
INTRODUCTION	7
THE LOCOMOTIVE	17
LOCOMOTIVE ENGINEERS	21
THEORY OF THE LOCOMOTIVE	24
WATER	25
Table showing the Weight of Water	31
Table showing the Weight of Water at Different Temperatures	32
Table showing the Boiling-point of Fresh Water at different Altitudes above Sea-level	33
AIR	33
Table showing the Expansion of Air by Heat, and the Increase of Bulk in proportion to Increase of Temperature	37
Resistance of Air against Railroad Trains	38
Table showing the Resistance of Air against Railroad Trains	40
COMPARATIVE SCALE OF ENGLISH, FRENCH, AND GERMAN THERMOMETERS	42
THE THERMOMETER	43
Rules for comparing Degrees of Temperature indicated by different Thermometers	47

	PAGE
ELASTIC FLUIDS AND VAPORS	49
CALORIC	51
HEAT	52
Latent Heat of various Substances	61
Table showing the Effects of Heat upon different Bodies	61
COMBUSTION	63
Compositions of different kinds of Anthracite Coal	66
Table showing the Total Heat of Combustion of various Fuels	74
Table of Temperatures required for the Ignition of different Combustible Substances	75
GASES	76
STEAM	80
Table showing the Velocity with which Steam of different Pressures will flow into the Atmosphere or into Steam of lower Pressure	89
Rule for finding the Superficial Feet of Steam-pipe required to Heat any Building with Steam	89
Table showing the Temperature of Steam at different Pressures from 1 pound per Square Inch to 240 pounds, and the Quantity of Steam produced from a Cubic Inch of Water, according to Pressure	91
HORSE-POWER OF STEAM-ENGINES	94
Rule for finding the Horse-power of Stationary Engines	99
THE POWER OF THE LOCOMOTIVE	101
Rule for finding the Horse-power of a Locomotive	102
Rules for calculating the Tractive Power of Locomotives	102
Table of Gradients	105

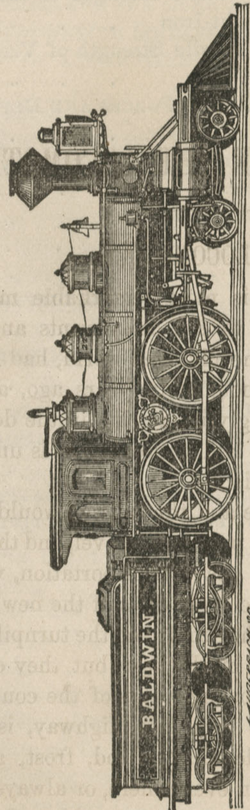
	PAGE
Adhesive Power of Locomotives	106
Rule for finding the Power of a Locomotive	106
Proportions of Locomotives, according to best Modern Practice	107
Proportions of different parts of Locomotives, according to best Modern Practice	113
Table showing the Travel of Valve and the Amount of Lap and Lead for different Points of Cut-off, and the Distance the Steam follows the Piston on the Forward Motion	116
RULES	117
LOCOMOTIVE BUILDING	118
CONSTRUCTION OF LOCOMOTIVES	118
SETTING THE VALVES OF LOCOMOTIVES	121
DEAD WEIGHT OF LOCOMOTIVES	126
Table showing the number of Revolutions per minute made by Drivers of Locomotives of different Diameters and at different Speeds	129
STEAM-PORTS	132
BRIDGES	133
ECCENTRICS	134
ECCENTRIC RODS	136
Formula by which to find the Positions of the Eccentric on the Shaft	137
THE SLIDE-VALVE	139
FRICTION ON THE SLIDE-VALVE	143
LAP AND LEAD OF VALVE	144
BALANCED SLIDE-VALVE	145
Table showing the amount of Lap and Lead on the Valves of Locomotives in Practice, on 35 of the principal Railroads in this Country	146
THE LINK	147

PAGE
ADJUSTMENT OF THE LINK 152
STEAM AND SPRING CYLINDER PACKING FOR LOCOMOTIVES 154
PACKING FOR THE PISTONS AND VALVE-RODS OF LOCOMOTIVES 156
Rule for finding the size of Piston- and Valve-Rod Packing 158
BRASSES FOR DRIVING-AXLES OF LOCOMOTIVES . 159
LATERAL MOTION 160
SPEED INDICATORS 161
LOCOMOTIVE BOILERS 163
PROPORTIONS OF THE LOCOMOTIVE BOILER, FROM THE BEST MODERN PRACTICE 167
WAGON-TOP AND STRAIGHT BOILERS 167
THE EVAPORATIVE POWER OF LOCOMOTIVE BOILERS 170
HEATING SURFACE, STEAM ROOM, AND WATER SPACE IN LOCOMOTIVE BOILERS 172
HEATING SURFACE TO GRATE SURFACE IN STEAM BOILERS 174
Rule for finding the Heating Surface in Locomotive boilers 174
Rule for finding the Heating Surface in the Tubes of Locomotive Boilers 175
Rule for finding the Heating Surface in Stationary Boilers 175
PUNCHED AND DRILLED HOLES FOR THE SEAMS OF LOCOMOTIVE BOILERS 176
MACHINE AND HAND RIVETING FOR LOCOMOTIVE BOILERS 179
COMPARATIVE STRENGTH OF SINGLE AND DOUBLE RIVETED BOILER SEAMS 180

PAGE
Rule for finding safe Working Pressure of any Boiler 183
Rule for finding the safe Working Pressure of Steel Boilers 184
Rule for finding the safe External Pressure on Boiler Flues 185
DEFINITIONS AS APPLIED TO BOILERS AND BOILER MATERIALS 186
EXPLANATION OF TABLE OF BOILER PRESSURES . 187
Rule for finding the Aggregate Strain caused by the Pressure of Steam on the Shells of Locomotive Boilers 187
Table of safe Internal Pressures for Steel Boilers 188
FURNACES OF LOCOMOTIVE BOILERS 192
PROPORTIONS OF FIRE-BOXES, FROM THE BEST MODERN PRACTICE 198
STRENGTH OF STAYED SURFACES IN THE FURNACES OF LOCOMOTIVE BOILERS 199
STAY-BOLTS 201
CROWN-BARS 203
TUBES 203
Table of Superficial Areas of External Surfaces of Tubes of Various Lengths and Diameters in Square Feet 206
COMBUSTION OF FUEL IN LOCOMOTIVE FURNACES 210
SMOKE-BOX 213
SMOKE-STACKS 214
EXHAUST-NOZZLE 216
SAFETY-VALVES 217
Table showing the Rise of the Safety-valves . 220
STEAM-GAUGES 221

PAGE
INSTRUCTIONS FOR THE CARE AND MANAGEMENT OF LOCOMOTIVE BOILERS 222
FIREMEN ON LOCOMOTIVES 224
FIRING 228
THE INJECTOR 231
RUE'S "LITTLE GIANT" INJECTOR . . . 233–236
Table of Capacities of Injectors 237
SIGNALS 238
WRECKING TOOLS 239
USEFUL NUMBERS IN CALCULATING WEIGHTS, MEASURES, ETC 241
MENSURATION OF THE CIRCLE, CYLINDER, ETC. . 242
Table of Decimal Equivalents to the Fractional Parts of a Gallon or an Inch 245
Table containing the Diameters, Circumferences, and Areas of Circles, and the Contents of each in Gallons at one foot in Depth . . . 246
Table showing the Weight of Water in Pipe of various Diameters one foot in Length . . 249
RULES 250
RULES FOR FINDING THE ELASTICITY OF STEEL SPRINGS 252
Table deducted from Experiments on Iron Plates for Steam-Boilers, by the Franklin Institute, Philada. 255
Table showing the Result of Experiments made on different Brands of Boiler Iron at the Stevens' Institute of Technology, Hoboken, N. J. . . 255
Table showing the Actual Extension of Wrought-Iron at various Temperatures 256
Table showing the Tensile Strength of various Qualities of Cast-iron 257

PAGE
Table showing the Tensile Strength of various Qualities of Wrought-Iron 258
Table showing the Tensile Strength of Various Qualities of Steel Plates 259
CENTRAL AND MECHANICAL FORCES AND DEFINITIONS 260
Table containing Diameters, Circumferences, and Areas of Circles, etc. 267
INCRUSTATION IN STEAM-BOILERS 272
BOILER EXPLOSIONS 278
ACCIDENTS 285
TABLE SHOWING THE TIME AT 80 DIFFERENT PLACES 289
DISTANCE BY RAILROAD BETWEEN IMPORTANT PLACES IN THE UNITED STATES . . . 292
DISTANCES FROM PHILADELPHIA TO CITIES AND TOWNS IN THE UNITED STATES BY THE SHORTEST ROUTES 295
VOCABULARY OF TECHNICAL TERMS AS APPLIED TO THE DIFFERENT PARTS OF LOCOMOTIVES . 299
INDEX 317



BALDWIN PASSENGER LOCOMOTIVE.

The perfection to which the locomotive is now brought makes it a marvel which no familiarity seems in the least to diminish. The tremendous power which it generates, the capacity of draft, the speed it attains, its perfect docility, and the ease with which it does its complicated work, have no parallel among human inventions.

HAND-BOOK OF THE LOCOMOTIVE

THE LOCOMOTIVE.

THE history of this most remarkable machine, now so necessary to the daily wants and commercial interests of the civilized world, had its useful commencement about forty years ago, and yet much that is exceedingly interesting in the detail of its early introduction and improvement is unknown to the present generation.

That the locomotive and the railway would supersede the steamboat for passenger travel, and the canal and turnpike road for heavy transportation, was not to be thought of in the early days of the new power. It was true the river, the canal, and the turnpike road had done good service in the past, but they did not keep pace with the growing wants of the country.

The river, nature's own free highway, is, when navigable, often hindered by flood, frost, and by drought, nor did it run everywhere, or always where it would best conduce to man's use and benefit. The slow, plodding canal did its work cheaply, and, with nothing better, it must have continued the favorite means for inland trade. But canals are only possible where water can be had in abundance to keep them full; and with winter's cold to interrupt their movements, they are practically useless for half the year. Their capacity, at best, is limited in many ways.

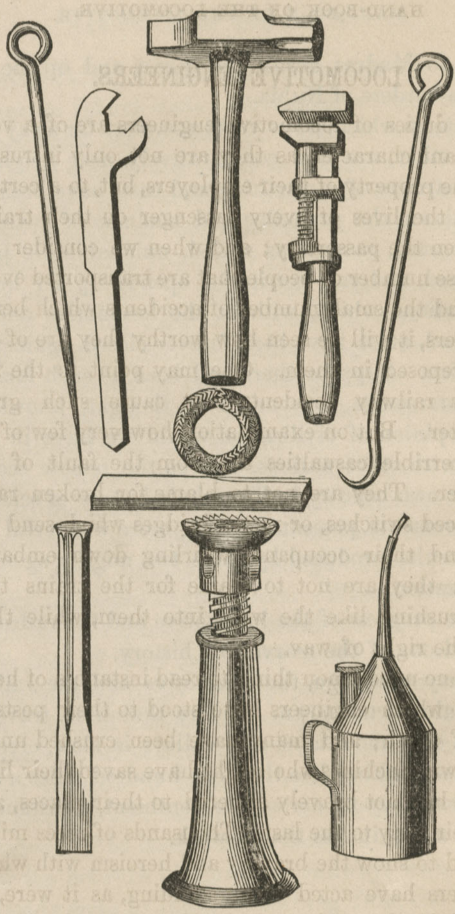
The turnpike road, very good in its place, had a very narrow limit of usefulness, when the means to do the carrying trade of a continent were to be attained. Man's restless nature longed for and demanded something better than the river, the canal, or the turnpike road; and this has been found in the railroad and the locomotive.

The railroad and the locomotive have already united the Atlantic and the Pacific shores, climbing the Sierras and winding their tortuous course down their slopes, dropping, as though it were, villages, towns, and cities in their path. What is true of this country, as regards the railroad and locomotive, is also true of other lands, for to-day the locomotive is thundering under the Alps and Apennines, across the plains of Russia, eastward to Siberia, down the Danube, from central Europe to Constantinople, and from Smyrna to Ephesus, rushing onward to the Euphrates; and before long the scream of the locomotive will be heard on the banks of that river, joining the network of European railways with the web already spun in India — reaching from the Indus to Calcutta, from Bombay to Burmah, from the Himalayas to Madras, across the desert and up the Nile to the borders of Nubia.

Nations which, a few years ago, were far away from each other, are now comparatively near neighbors. The barriers of superstition and caste have been broken down, the prejudice and manners of years revolutionized, mountains scaled, uninhabitable plains spanned, and vast territories opened up for human habitations which, without the locomotive and the railroad, must have been forever closed against civilization. Suppose there had been no such facilities for intercourse, how much of thought, knowledge, and opinion of civilization would we have in common with other nations, or even the remote sections of our own country? The whole history of scientific achievements presents nothing more wonderful than the results produced by these two mighty agents of civilization.

The progress of the locomotive and the railroad is indeed one of the marvels of history.

Forty years ago, the locomotive and the railroad were almost unknown. Before that time, travellers toiled over mountains and valleys in slow, creeping coaches, making less than one hundred miles a day; but now they fly across the continent, a distance of 3,500 miles, in less than a week.



THE ENGINEER'S CHART.

LOCOMOTIVE ENGINEERS.

The duties of locomotive engineers are of a very important character, as they are not only intrusted with the property of their employers, but, to a certain extent, the lives of every passenger on their trains, and even the passers-by; and when we consider the immense number of people that are transported every day, and the small number of accidents which befall travellers, it will be seen how worthy they are of the trust reposed in them. One may point to the numerous railway accidents that cause such great slaughter. But on examination, how very few of all these terrible casualties are from the fault of the engineer. They are not to blame for broken rails, misplaced switches, or rotten bridges which send the cars and their occupants whirling down embankments; they are not to blame for the trains that come rushing like the wind into them, while they have the right of way.

It is no uncommon thing to read instances of heroism in which engineers have stood to their posts in face of death; and many have been crushed under their own machines who might have saved their lives if they had not bravely adhered to their places, and did their duty to the last. Thousands of cases might be cited to show the bravery and heroism with which engineers have acted while standing, as it were, on the brink of eternity, which, if seen on the battlefield, or on the quarter-deck of a steamer, would have called forth universal applause.

"No soldier in the battle's shock needs more to cast out fear,
And hold his soul firm as a rock, than does an engineer;
And he who might from the battle flee, or yield his soul to fear,
Might still perhaps a warrior be, but never an engineer."

The heroism that deliberately accepts positions of danger when its appreciation by others is not manifested, can hardly be accounted for on the supposition of its accompanying excitement; the incentive seems to be disproportioned to the responsibilities. In cases where the performer knows that the community looks on approvingly and wonderingly, as in the case of the fireman who risks his own life to save that of another, or the soldier who exposes himself to hostile bullets, it is easy to understand the impelling motive. But in such a case as that of the locomotive engineer, whose importance is scarcely recognized, and whose labors and risks are seldom fully appreciated, it would seem that a noble sense of duty and a heroic sentiment of self-denial must be the impelling cause for following so dangerous a profession.

It is almost an every-day occurrence for passengers on steamships, after arriving safely in port, to assemble and pass complimentary resolutions to the fidelity and watchfulness of the captain, although the discharge of the duties that devolve on him did not involve the exercise of either bravery or heroism.

But who ever read of the passengers on a railway train assembling in a depot, and passing complimentary resolutions to the engineer that carried them safely to their homes, or to the end of their journey? Nor does he seem to have any considerate human sympathy as he stands on his foot-board and guides the ponderous engine through rocky defiles, over trestle-work, culvert, and bridge, around the edge of a mountain spur, through the streets of a town, frequently in darkness.

Like a soldier begrimed in battle's dark strife,
And brave to the cannon's hot breath,
He too plunges on, with his long train of life,
Unmindful of danger and death.

Although the love of excitement, or the gratification of daring danger, may influence some who seek the position of a locomotive engineer, yet it is not so with all the responsibilities assumed. The dangers and exposures to be encountered deserve a more generous recognition than they generally receive. But when the time shall come that labor will occupy its proper position, and the mechanic stand at the head of the useful professions, the locomotive engineer will fill no second-rate niche. He stands even to-day above his brother mechanics, inasmuch as qualities of mind not requisite in the shop are absolutely necessary to success in his vocation.

THEORY OF THE LOCOMOTIVE.

WATER.

AIR. THERMOMETERS. ELASTIC FLUIDS.

CALORIC.

HEAT. COMBUSTION. GASES.

STEAM.

WATER.

Pure water in nature does not exist, nor is it to be found in the laboratory of the chemist. Fortunately, however, it happens that pure water is not necessary, or even desirable, for household or manufacturing purposes. The presence of air or other gases adds greatly to the ease with which steam may be generated; the ammonia that is present in most water improves it for manufacturing purposes, and it has been abundantly proved that the salts which are present in most well-waters add greatly to their wholesomeness.

But at the same time it must be remembered that some waters contain impurities which render them unfit for use. Of these various impurities the insoluble portion is in general the least injurious, though it is frequently the most offensive.

Water swarming with minute animalcules, or turbid with the clay and sand that has been stirred up from the bed of some stream, may be offensive though it is not dangerous; while, on the other hand, water may be beautifully clear to the eye and not very offensive to the taste, and yet hold in solution the most deadly poison, in the form of dissolved salts or the soluble portions of animal excreta.

It also happens that these insoluble matters are easily and cheaply removed, while the utmost care is required to free water from matter which exists in a dissolved state.

The Composition of Water. — Pure water is composed of the two gases, hydrogen and oxygen, in the proportions of 2 measures of hydrogen to 1 of oxygen, or, 1 weight of hydrogen to 8 of oxygen; or, oxygen 89 parts by weight, and by measure 1 part, hydrogen, by weight, 11 parts, and by measure 2 parts.

The specific gravity of all waters is not the same. The following table will show the specific gravity of different seas.

	Weight of water being 1000	Weight of an imperial gallon in pounds.
Water from the Dead Sea	1240	12.4
" " " Mediterranean	1029	10.3
" " " Irish Channel	1028	10.2
" " " Baltic Sea	1015	10.2

For the production of steam all waters are not equal. Water holding salt in solution, earth, sand or mud in suspension, requires a higher temperature to produce steam of the same elastic force than that generated from pure water.

Water, like all other fluids and gases, expands with heat and contracts with cold down to 39° Fah.

If water be boiled in an open vessel it is impossible to raise the temperature above 212° Fah., as all the surplus heat which may be applied passes off with the steam.

If heat be applied to the top of a vessel, ebullition will not take place, as very little heat would be communicated to other parts of the vessel, and the water would not boil.

Ebullition, or boiling of water or other liquids, is effected by the communication of heat through the separation of their particles.

The evaporation of water is the conversion of water as a liquid into steam as a vapor.

Latent Heat of Fusion. — If a pound of ice at 32° Fah. be mixed with a pound of water at 174°, the water will gradually dissolve the ice, being just sufficient for that purpose, and the residuum will be two pounds of water at 32° Fah.

The 142° units of heat which are apparently lost having been employed in performing a certain amount of work, *i. e.*,* in melting the ice or separating the molecules and giving them another shape, and as all work requires a supply of heat to do it, these 142° units have been consumed in performing the work necessary to melt the ice.

Therefore, if the pound of water were reconverted into ice, it would have to be deprived of 142° of heat. Hence we see why the lost heat is called latent heat, that is, heat not shown by the thermometer.

* *i. e.*, that is.

Suppose that we have a pound of ice, at a temperature of 32° Fah., and that we mix it with a pound of water at 212°, the ice will be melted and we shall have two pounds of water at a temperature of 51°.

Now, if we take a pound of water at a temperature of 32° and mix it with a pound of water at 212°, the resulting mixture of the two pounds will have a temperature of 122°. Hence we see that the ice, in melting, has absorbed enough heat to raise two pounds of water through a temperature of 122° — 51° = 71°, or one pound through 142°, and we say that the latent heat of the liquefaction of water is 142°.

The latent heat of the evaporation of water can be determined in a similar manner by condensing a pound of steam at 212° Fah. with a given weight of water at a known temperature, and also by mixing a pound of water at a temperature of 212° Fah. with the same amount of water as was employed in the case of the steam, and observing the difference of temperature of the resulting mixtures.

Thus, a pound of water at 212° mixed with ten pounds at 60° gives eleven pounds at 74°. A pound of steam at 212° mixed with ten pounds of water at 60° gives eleven pounds of water at 162°. In other words, the steam on being condensed has given out heat (which was not previously sensible to the thermometer) enough to raise eleven pounds of water through a temperature of 162° less 74° equals 88°, or one pound through 968°, and we say that the latent heat of steam is 968°. Other authorities give 965°, 966°.

If a pound of mercury and a pound of water be heated to the same temperature and allowed to cool, it will be found that the mercury cools 30 times as fast as the water; hence we say that the specific heat of mercury is about one-thirtieth that of water.

The boiling-point of water is that temperature at which the tension of its vapor exactly balances the pressure of the atmosphere. But the temperature at which the ebullition of water begins depends upon the elasticity of the air or other pressure.

At the level of the sea, the barometer standing at 29.905 (or nearly 30) inches of mercury, water will boil at 212° Fah.; but the higher we ascend above the level of the sea, the more the boiling-point diminishes.

Water attains its greatest density at 39° Fah., or 7° above freezing.

Water presses equally in every direction, finds its own level, and can be compressed $\frac{1}{100}$ of an inch in every 40,000 feet by each atmosphere or pressure of 15 pounds to the square inch of pressure applied; but when the pressure is removed, its elasticity restores it to its original bulk.

Water becomes solid and crystallized as ice owing to the abstracting of its heat.

The force of expansion exerted by water in the act of freezing has been found irresistible in all mechanical experiments to prevent it.

Water in a vacuum boils at about 98 degrees Fahrenheit, and assumes a solid at 32 degrees in the atmosphere, when it expands $\frac{1}{12}$ its original bulk.

Water, after being long kept boiling, affords an ice more solid, and with fewer air bubbles, than that which is formed from unboiled water.

Pure water, kept for a long time in vacuo, and afterwards frozen there, freezes much sooner than common water exposed to the same degree of cold in the open atmosphere.

Ice formed of water thus divested of its air, is much more hard, solid, heavy, and transparent than common ice.

Ice, after it is formed, continues to expand by decrease of temperature; to which fact is probably attributable the occasional splitting and breaking up of the ice on ponds, etc.

A cubic foot of water weighs 62½ pounds; a cubic foot of ice weighs 57.5 pounds. It follows that ice is nearly one-twelfth lighter than water.

Now, if heat be applied to ice, the temperature of which is below freezing, the temperature will soon rise to 32° or freezing, but any further application of heat cannot increase the temperature of the ice until the whole mass is melted.

The specific gravity of ice is .92, and specific gravity of water is 1.000 — water being the standard by which to obtain the specific gravity of all solids, fluids, and even gases. Though air is sometimes

used as a standard for gases, water is more commonly used.

The specific gravity of water is the comparative weight of a given bulk of water to the same bulk of any other liquid. Thus, if we take equal measures of the several different liquids, we shall find that they possess very different weights.

The weight of a pint of water, a pint of oil, and a pint of mercury will differ very materially. The mercury will weigh 13.6 times more than water does, and the water will weigh a good deal more than the oil.

TABLE

SHOWING THE WEIGHT OF WATER.

1	Cubic inch	is equal to	.036	pounds.
12	Cubic inches	"	.432	"
1	Cubic foot	"	62.5	"
1	Cubic foot	"	7.50	U. S. gallons.
1.8	Cubic foot	"	112.00	pounds.
35.8	Cubic feet	"	2240.00	"
1	Cylindrical inch	"	.02827	"
12	Cylindrical inches	"	.339	"
1	Cylindrical foot	"	49.08	"
1	Cylindrical foot	"	6.00	U. S. gallons.
2.282	Cylindrical feet	"	112.00	pounds.
45.64	Cylindrical feet	"	2240.00	"
11.2	Imperial gallons	"	112.00	"
224	Imperial gallons	"	2240.00	"
13.44	U. S. gallons	"	112.00	"
268.8	U. S. gallons	"	2240.00	"

TABLE
SHOWING THE WEIGHT OF WATER AT DIFFERENT TEMPERATURES.

Temperature Fahrenheit.	Weight of a Cubic Foot in Pounds.	Temperature Fahrenheit.	Weight of a Cubic Foot in Pounds.
40°	62.408	172°	60.72
42°	62.406	182°	60.5
52°	62.377	192°	60.28
62°	62.321	202°	60.05
72°	62.25	212°	59.82
82°	62.15	230°	59.37
92°	62.04	250°	58.85
102°	61.92	275°	58.17
112°	61.78	300°	57.42
122°	61.63	350°	55.94
132°	61.47	400°	54.34
142°	61.30	450°	52.70
152°	61.11	500°	51.02
162°	60.92	600°	47.64

Water attains a minimum volume and a maximum density at 39° Fah.; any departure from that temperature in either direction is accompanied by expansion, so that 8° or 10° of cold produces about the same amount of expansion as 8° or 10° of heat.

ANALYSIS OF WATER TAKEN FROM SIX DIFFERENT WELLS.

Chloride sodium, 9.162 grains in a gallon.
Carbonate lime, 7.103 " " "
Carbonate magnesia, 3.027 " " "
Sulphate lime, alumina, lithia, a trace of each.
Chloride sodium, 9.087 grains in a gallon.
Carbonate lime, 5.532 " " "

TABLE
SHOWING THE BOILING-POINT OF FRESH WATER AT DIFFERENT ALTITUDES ABOVE SEA-LEVEL.

Boiling point in deg. Fah.	Altitude above sea-level in feet.	Boiling point in deg. Fah.	Altitude above sea-level in feet.	Boiling point in deg. Fah.	Altitude above sea-level in feet.
184°	15221	195°	9031	206°	3115
185	14649	196	8481	207	2589
186	14075	197	7932	208	2063
187	13498	198	7381	209	1539
188	12934	199	6843	210	1025
189	12367	200	6304	211	512
190	11799	201	5764	212	sea-level=0
191	11243	202	5225		
192	10685	203	4697	Below sea-level.	
193	10127	204	4169	213°	511
194	9579	205	3642		

AIR.

The atmosphere is known to extend at least 45 miles above the earth.

Its composition is about 79 measures of nitrogen gas and 21 of oxygen; or in other words, air consists of, by volume, oxygen 21 parts, nitrogen 79 parts; by weight, oxygen 77 parts, nitrogen 23 parts.

According to Dr. Prout, 100 cubic inches of air at the surface of the earth, when the barometer stands at 30 inches, and at a temperature of 60° Fah., weighs about 31 grains, being thus about 815 times lighter than water, and 11,065 times lighter than mercury.

Since the air of the atmosphere is possessed of weight, it must be evident that a cubic foot of air at the surface of the earth has to support the weight of all the air directly above it, and that, therefore, the higher we ascend up in the atmosphere the lighter will be the cubic foot of air, or in other words, the farther from the surface of the earth, the less will be the density of the air.

At the height of three and a half miles it is known that the atmospheric air is only half as dense as it is at the surface of the earth.

From the nature of fluids, it follows, that the air of the atmosphere presses against any body which comes into contact with it; because fluids exert pressure in all directions, — upwards, downwards, sidewise, and oblique.

It is also known that the pressure on any point is equal to the weight of all the particles of the fluid in a perpendicular line between the point in contact and the surface of the fluid.

The amount of pressure of a column of air whose base is one square foot, and altitude the height of the atmosphere, has been found to be 2156 pounds avoirdupois, or very nearly 15 pounds of pressure on every square inch; consequently, it is common to state the pressure of the atmosphere as equal to 15 pounds on the square inch.

If any gaseous body or vapor, such as steam, exerts a pressure equivalent to 15 pounds on the square

inch, then the force of that vapor is said to be equal to one atmosphere; if the vapor be equal to 30 pounds on every square inch, then it is equal to two atmospheres, and so on. Consequently, the atmospheric pressure is capable of supporting about 30 inches of mercury, or a column of water 34 feet high.

It is also found that the pressure of the atmosphere is not constant even at the same place; at the equator, the pressure is nearly constant, but is subject to greater change in the high latitudes.

In some countries the pressure of the atmosphere varies so much as to support a column of mercury so low as 28 inches, and at other times so high as 31, the mean being 29.5, thus making the average pressure between 14 and 15 pounds on the square inch. But in scientific books, generally, the pressure is understood in round numbers to be 15 pounds, so that a pressure exerted equal to 1, 2, 3, 4, etc., atmospheres, means such a pressure as would support 30, 60, 90, 120, etc., inches of mercury in a perpendicular column, or 15, 30, 45, 60, etc., pounds on every square inch.

Air is a very slow conductor of heat, and is sometimes used as a non-conductor in hollow walls to prevent the radiation of heat.

The pressure of the air differs at different latitudes; for instance, at 7 miles above the surface of the earth the air is four times lighter than it is at the earth's surface; at 14 miles it is 16 times lighter, and at 21 miles it is 64 times lighter.

Under a pressure of 5½ tons to the square inch, air becomes as dense, and would weigh as much per cubic foot, as water.

The greatest heat of air in the sun is about 140° Fah., and it probably never exceeds 145° Fah.

If a given weight of air at 0° Fah. be raised in temperature to 461° Fah. under a constant pressure, it is expanded to twice its original volume; and if heated from 0° Fah. to twice 461°, or 922°, its original volume is trebled.

One cubic foot of pure air at 62° Fah. and 14.7 pounds per square inch pressure weighs .076097 pound, 1.217 ounces or 532.7 grains.

Although the atmosphere may extend to the height of 45 miles, yet its lower half is so compressed as to occupy only 3½ miles, so greatly do the upper portions expand when relieved from pressure. Hence, at the height of 3½ miles, the elasticity of the atmosphere is $\frac{1}{2}$; at 7 miles, $\frac{1}{4}$; at 10½ miles, $\frac{1}{8}$; at 14 miles, $\frac{1}{16}$, etc.

For the above reasons a pump in a higher region will not lift water to as great a height as in a lower one. It is also stated that the temperature of the atmosphere lowers or becomes colder at the rate of 1° Fah. for each 300 feet of ascent above the earth's surface; but this is liable to many exceptions, and varies much with local causes.

TABLE

SHOWING THE EXPANSION OF AIR BY HEAT, AND THE INCREASE OF BULK IN PROPORTION TO INCREASE OF TEMPERATURE.

Fahrenheit.		Bulk.	Fahrenheit		Bulk.
Temp. 32	Freezing-point.	1000	Temp. 75	Temperate	1099
" 33	"	1002	" 76	Summer heat.	1101
" 34	"	1004	" 77	"	1104
" 35	"	1007	" 78	"	1106
" 36	"	1009	" 79	"	1108
" 37	"	1012	" 80	"	1111
" 38	"	1015	" 81	"	1112
" 39	"	1018	" 82	"	1114
" 40	"	1021	" 83	"	1116
" 41	"	1023	" 84	"	1118
" 42	"	1025	" 85	"	1121
" 43	"	1027	" 86	"	1123
" 44	"	1030	" 87	"	1125
" 45	"	1032	" 88	"	1128
" 46	"	1034	" 89	"	1130
" 47	"	1036	" 90	"	1132
" 48	"	1038	" 91	"	1134
" 49	"	1040	" 92	"	1136
" 50	"	1043	" 93	"	1138
" 51	"	1045	" 94	"	1140
" 52	"	1047	" 95	"	1142
" 53	"	1050	" 96	Blood heat....	1144
" 54	"	1052	" 97	"	1146
" 55	"	1055	" 98	"	1148
" 56	Temperate ...	1057	" 99	"	1150
" 57	"	1059	" 100	"	1152
" 58	"	1062	" 110	Fever heat 112	1173
" 59	"	1064	" 120	"	1194
" 60	"	1066	" 130	"	1215
" 61	"	1069	" 140	"	1235
" 62	"	1071	" 150	"	1255
" 63	"	1073	" 160	"	1275
" 64	"	1075	" 170	Spirits boil 176	1295
" 65	"	1077	" 180	"	1315
" 66	"	1080	" 190	"	1334
" 67	"	1082	" 200	"	1364
" 68	"	1084	" 210	"	1372
" 69	"	1087	" 212	Water boils...	1375
" 70	"	1089	" 302	"	1558
" 71	"	1091	" 392	"	1739
" 72	"	1093	" 482	"	1919
" 73	"	1095	" 572	"	2098
" 74	"	1097	" 680	"	2312

Resistance to Motion caused by the Atmosphere. — The resistance against a body moving in a fluid at rest is less than the resistance experienced by the same body placed at rest, in a fluid moving against it, which seems to denote that a fluid in motion separates itself less easily than a fluid at rest.

Thin plates meet with a greater resistance from the air than a prismatic body presenting the same surface, and the resistance diminishes according as the prism is longer.

But if the moving body be a lengthened prism, the air in passing along its sides loses a certain proportion of its velocity, and, consequently, on reaching the hind-face of the prism, extends itself behind it with a force partially diminished, consequently producing a partial vacuum.

RESISTANCE OF AIR AGAINST RAILROAD TRAINS.

To dispense with all calculation relative to the resistance of the air, the following table (pp. 40, 41) is subjoined to show its intensity for all velocities from 5 to 35 miles per hour, and for surfaces of from 10 to 100 square feet.

Were it required to perform the calculation for a velocity not contained in the table, it would evidently suffice to seek the resistance corresponding to half that velocity, and to multiply the resistance found by 4. Or, on the contrary, to seek the resistance corresponding to the double of the given velocity, and to take a quarter of the result.

The resistance of the air against a surface of 100 square feet, at the velocity of 50 miles per hour, is equal to four times the resistance of the air against the same surface at 25 miles per hour.

By means of the table in question will be obtained, without calculation, the resistance of the air expressed in pounds for any velocity of the moving body. But it must be understood that the table supposes the atmosphere to be at rest.

If, then, there be a wind of some intensity, favorable to the motion, or contrary to it, account must be taken of that, and in order to effect this, it will be necessary to observe that if the wind is opposed, the train will move through the air with the velocity equal to the difference between its own absolute velocity and that of the wind.

But if, on the contrary, the wind is favorable to the motion, the effect of the velocity of the train through the air will be equal to the sum of its own velocity augmented by that of the wind.

On such cases the velocity of the wind must be first measured by noting the time taken by some light body, such as paper, in traversing a space previously measured on the ground.

If the wind, instead of being precisely contrary or favorable to the motion, should exert its action in an oblique direction, it would tend to displace all the cars laterally, and, consequently, from the conical form of the wheels, all those on the farther side from the wind would turn on a different diameter than those on the side towards the wind.

The resistance produced will, therefore, be the same as that which would take place on a curve on which the effect of the centrifugal forces were not corrected, and that resistance would necessarily be very considerable.

TABLE

SHOWING THE RESISTANCE OF AIR AGAINST RAILROAD TRAINS.

Velocity of motion in miles per hour.	Resistance of the air in pounds per square feet of surface.	*Resistance of the air in pounds; the effective surface of the train in square feet, being*								
		20 ft.	30 ft.	40 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.
miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5	.07	1	2	3	3	4	5	5	6	7
6	.10	2	3	4	5	6	7	8	9	10
7	.13	3	4	5	7	8	9	11	12	13
8	.17	3	5	7	9	10	12	14	15	17
9	.22	4	7	9	11	13	15	17	20	22
10	.27	5	8	11	13	16	19	22	24	27
11	.33	7	10	13	16	20	23	26	29	33
12	.39	8	12	15	19	23	27	31	35	39
13	.45	9	14	18	23	27	32	36	41	45
14	.53	11	16	21	26	32	37	42	47	53
15	.60	12	18	24	30	36	42	48	54	60
16	.69	14	21	28	34	41	48	55	62	69
17	.78	16	23	31	39	47	54	62	70	78
18	.87	17	26	35	44	52	61	70	78	87
19	.97	19	29	39	49	58	68	78	87	97
20	1.07	22	32	43	54	65	75	86	97	107
21	1.19	24	36	47	59	71	83	95	107	119
22	1.30	26	39	52	65	78	91	104	117	130
23	1.42	28	43	57	71	85	100	114	128	142
24	1.55	31	47	62	78	93	109	124	140	155

TABLE—(*Continued*)

SHOWING THE RESISTANCE OF AIR AGAINST RAILROAD TRAINS.

Velocity of motion in miles per hour.	Resistance of the air in pounds per square feet of surface.	*Resistance of the air in pounds; the effective surface of the train in square feet, being*								
		20 ft.	30 ft.	40 ft.	50 ft.	60 ft.	70 ft.	80 ft.	90 ft.	100 ft.
miles.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
25	1.68	34	50	67	84	101	118	134	151	168
26	1.82	36	55	73	91	109	127	146	164	182
27	1.96	39	59	78	98	118	137	157	176	196
28	2.11	42	63	84	106	127	148	169	190	211
29	2.26	45	68	90	113	136	158	181	203	226
30	2.42	48	73	97	121	145	169	194	218	242
31	2.58	52	77	103	129	155	181	206	232	258
32	2.75	55	83	110	138	165	193	220	248	275
33	2.93	59	88	117	147	176	205	234	264	293
34	3.11	62	93	124	156	187	218	249	280	311
35	3.29	66	99	132	165	197	230	263	296	329

Rule to calculate Resistance of Train at a given speed.

Square the speed in miles per hour, divide this by 171, and add 8 to the quotient. Result is the resistance at the rails in pounds per ton weight.

Resistance of Trains on a level at different speeds in pounds per Ton of Load.

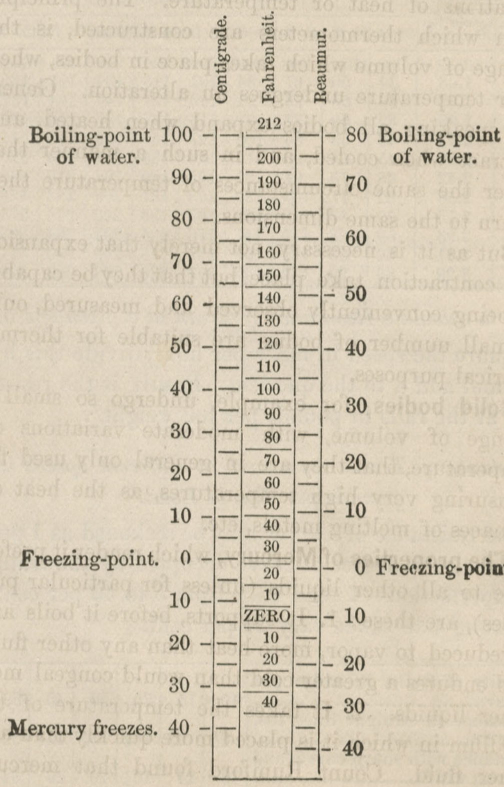
The resistance of curves may be reckoned as 1 per cent. for each degree of curve occupied by the train.

Imperfections of road vary from 5 to 40 per cent.

Strong side winds vary 20 per cent.

Velocity of trains in miles per hour.................................	10	15	20	30	40	50
Resistance on straight lines, lbs. per ton..................................	8½	9¼	10¼	13¼	17¼	22¼
Resistance with sharp curves and strong winds..........................	13	14	15½	20	26	34

COMPARATIVE SCALE OF ENGLISH, FRENCH, AND GERMAN THERMOMETERS.



THE THERMOMETER.

The Thermometer is an instrument for measuring variations of heat or temperature. The principle upon which thermometers are constructed, is the change of volume which takes place in bodies, when their temperature undergoes an alteration. Generally speaking, all bodies expand when heated, and contract when cooled, and in such a manner that under the same circumstances of temperature they return to the same dimensions.

But as it is necessary, not merely that expansion and contraction take place, but that they be capable of being conveniently observed and measured, only a small number of bodies are suitable for thermometrical purposes.

Solid bodies, for example, undergo so small a change of volume, with moderate variations of temperature, that they are in general only used for measuring very high temperatures, as the heat of furnaces of melting metals, etc.

The properties of Mercury, which render it preferable to all other liquids (unless for particular purposes), are these: 1. It supports, before it boils and is reduced to vapor, more heat than any other fluid, and endures a greater cold than would congeal most other liquids. 2. It takes the temperature of the medium in which it is placed more quickly than any other fluid. Count Rumford found that mercury was heated from the freezing- to the boiling-point of water in 58 seconds, while water took 133 seconds, and air 617 seconds, the heat applied being the same in all the three cases. 3. The variations of its volume, within limits, which include the temperatures most frequently required to be observed, are found to be perfectly regular and proportional to the variations of temperature.

The Mercurial Thermometer consists of a bulb and stem of glass of uniform bore. A sufficient quantity of mercury having been introduced, it is boiled to expel the air and moisture, and the tube is then hermetically sealed.

The standard points are ascertained by immersing the thermometer in melting ice, and in the steam of water boiling under the pressure of 14.7 pounds on the square inch, and marking the positions of the top of the column; the interval between those points is divided into the proper number of degrees — 100 for the Centigrade scale; 180 for Fahrenheit's; and 80 for Reaumur's.

In Fahrenheit's time it was supposed that the greatest degree of cold attainable was reached by mixing snow and common salt, or snow and sal-ammoniac. A thermometer plunged into a mixture of this kind was found to fall much below the point indicated by melting ice. The point to which the mercury fell by contraction, when plunged in this mixture, Fahrenheit marked 0; the interval between this and the freezing-point he divided into

thirty-two equal divisions, hence the freezing-point came to be indicated by 32°.

Then equal divisions were continued upwards, and the mercury, by expansion, reaching 212°, when the thermometer was immersed in boiling water, this 212° was called the boiling-point. This is briefly the reason for Fahrenheit adopting his method of division, and why he has 212° — 32° = 180° between the freezing and the boiling points.

But a much lower temperature than Fahrenheit's 0° has been observed in cold countries, and as mercury becomes solid at 39° Fahrenheit below freezing, it would be the most accurate limit to the scale, as it would register the utmost extremes of heat and cold to which the mercurial thermometer is sensible.

Centigrade Scale. — On this scale the space between the freezing- and the boiling-points of water is divided into equal parts, the zero point being placed, as in Reaumur's, at freezing. This division being in harmony with our decimal arithmetic, is better adapted than Fahrenheit's or Reaumur's scale for scientific purposes.

Reaumur's Thermometer. — In Reaumur's thermometer the melting-point of ice is taken as zero, and the distance between that and the boiling-point for water is divided into 80 equal parts. Reaumur having observed that between those temperatures spirits of wine (which he used for the thermometric fluid) expanded from 1,000 to 1,080 parts. This division soon became general in France and other countries, and a great number of valuable observations have been recorded in terms of it; but it is now seldom used in works of science.

Change of Zero. — There is a circumstance connected with the mercurial thermometer which requires to be attended to, when very exact determinations of temperature are to be made, as it has been observed that when thermometers which have been constructed for several years are placed in melting ice, the mercury stands in general higher than the zero point of the scale; and this circumstance, which renders the scale inaccurate, has been usually ascribed to the slowness with which the glass of the bulb acquires its permanent arrangement, after having been heated to a high degree in boiling the mercury.

In very nice experiments it is always necessary to verify the zero point; for it was found that when thermometers have been kept during a certain time in a low temperature, the zero point rises, but falls when they have been kept in a high temperature, and this remark applies equally to old thermometers and to those which have been recently constructed.

Absolute Zero.—An absolute zero is a theoretical and imaginary term, as an absolute zero is only *supposed* to be the point where heat-motion ceased entirely, and is fixed at 461° Fah. below the zero of the common thermometer.

The rate of expansion of mercury with rise of temperature increases as the temperature becomes higher; from which it follows, that if a thermometer

showing the dilation of mercury simply were made to agree with an air thermometer at 32° and 212°, the mercurial thermometer would show lower temperatures than the air thermometer between those standard points and higher temperatures beyond them.

Spirit Thermometers are used to measure temperatures at and below the freezing-point of mercury. Their deviations from the air thermometer are greater than those of the mercurial thermometer.

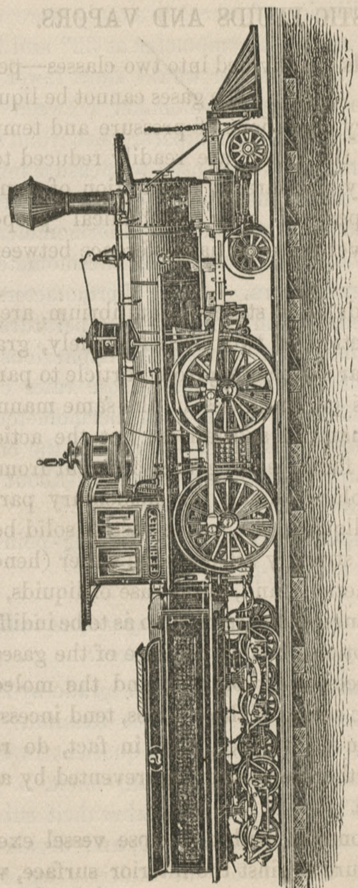
Solid Thermometers. — Solid thermometers are sometimes used, which indicate temperatures by showing the difference between the expansions of a pair of bars of two substances whose rates of expansion are different. When such thermometers are used to indicate temperatures higher than the boiling point of mercury under one atmosphere (about 676° Fah.), they are called Pyrometers.

Fixed Temperatures are the boiling-point for water and the melting-point for ice.

Rules for comparing Degrees of Temperature indicated by different Thermometers:

Rule I.—Multiply degrees of Centigrade by 9, and divide by 5; or multiply degrees of Reaumur by 9, and divide by 4. Add 32 to the quotient in either case, and the sum is degrees of Fahrenheit.

Rule II. — From degrees of Fahrenheit subtract 32; multiply the remainder by 5, and divide by 9 for degrees of Centigrade; or multiply by 4 and divide by 9 for degrees of Reaumur.



DANFORTH PASSENGER LOCOMOTIVE.

The locomotive stands to-day a proud monument of the skill and enterprise of American mechanical engineering.

ELASTIC FLUIDS AND VAPORS.

Elastic fluids are divided into two classes—permanent gases and vapors. The gases cannot be liquefied under ordinary conditions of pressure and temperature; whereas the vapors are readily reduced to the liquid form by pressure or diminution of temperature. In respect of their mechanical properties there is, however, no essential difference between the two classes.

Elastic fluids, in a state of equilibrium, are subject to the action of two forces: namely, gravity, and a molecular force acting from particle to particle.

Gravity acts on the gases in the same manner as on all other material substances; but the action of the molecular forces is altogether different from that which takes place among the elementary particles of solids and liquids; for, in the case of solid bodies, the molecules strongly attract each other (hence results their cohesion), and, in the case of liquids, exert a feeble or evanescent attraction, so as to be indifferent to internal motion; but, in the case of the gases, the molecular forces are repulsive, and the molecules, yielding to the action of these forces, tend incessantly to recede from each other, and, in fact, do recede until their further separation is prevented by an exterior obstacle.

Thus, air confined within a close vessel exerts a constant pressure against the interior surface, which is not sensible, only because it is balanced by the equal pressure of the atmosphere on the exterior surface. This pressure exerted by the air against the sides of a vessel within which it is confined, is called its elasticity, elastic force, or tension.

Conditions of Equilibrium.—In order that all the parts of an elastic fluid may be in equilibrium, one condition only is necessary: namely, that the elastic force be the same at every point situated in the same horizontal plane. This condition is likewise necessary to the equilibrium of liquids, and the same circumstances give rise to it in both cases: namely, the mobility of the particles, and the action of gravity upon them.

The density of bodies being inversely as their volumes, the law of Mariotte may be otherwise expressed by saying the density of an elastic fluid is directly proportional to the pressure it sustains. Under the pressure of a single atmosphere, the density of air is about the 770th part of that of water; whence it follows that, under the pressure of 770 atmospheres, air is as dense as water.

The average atmospheric pressure being thus equal to that of a column of water of about 34 feet in altitude at the level of the sea, at a depth of 26,180 (equals 770 multiplied by 34) feet, or 5 miles, air would be heavier than water; and though it should still remain in a gaseous state, it would be incapable of rising to the surface.

CALORIC.

The ordinary application of the word *heat* implies the sensation experienced on touching a body hotter, or of a higher temperature; whilst the term *caloric* provides for the expression of every conceivable existence of temperature.

Caloric is usually treated as if it were a material substance; but, like light and electricity, its true nature has yet to be determined.

Caloric passes through different bodies with different degrees of velocity. This has led to the division of bodies into *conductors* and *non-conductors* of caloric; the former includes such bodies as metals, which allow caloric to pass freely through their substance, and the latter comprises those that do not give an easy passage to it, such as stones, glass, wood, charcoal, etc.

Radiation of Caloric. — When heated bodies are exposed to the air, they lose portions of their heat by projections in right lines into space from all parts of their surface. Radiation is effected by the nature of the surface of the body: thus, black and rough surfaces radiate and absorb more heat than light and polished surfaces. Bodies which radiate heat best, absorb it best.

Reflection of Caloric differs from radiation, as the caloric is in this case reflected from the surface without entering the substance of the body. Hence.

the body which radiates, and consequently absorbs most caloric, reflects the least, and *vice versa.*

Latent caloric is that which is insensible to the touch, or incapable of being detected by the thermometer. The quantity of heat necessary to enable ice to assume the fluid state, is equal to that which would raise the temperature of the same weight of water, 142° Fah., and an equal quantity of heat is set free from water when it assumes the solid form.

Sensible caloric is free and uncombined, passing from one substance to another, affecting the senses in its passage, determining the height of the thermometer, and giving rise to all the results which are attributed to this active principle.

Evaporation produces cold, because caloric must be absorbed in the formation of vapor, a large quantity of it passing from a sensible to a latent state, the capacity for heat of the vapor formed being greater than that of the fluid from which it proceeds.

HEAT.

Heat is one form of mechanical power, or, more properly, a given quantity of heat is the equivalent of a determinate amount of mechanical power; and as heat is capable of producing power, so contrariwise power is capable of producing heat.

As it becomes necessary to have a standard for measuring the amount of heat absorbed or evolved during any operation, in this country the standard unit is the amount of heat necessary to raise the temperature of a pound of water 1° Fah., or from 32° to 33° Fah.

Specific Heat.—Different bodies require very different quantities of heat to effect in them the same change of temperature. The capacity of a body for heat is termed its "specific heat," and may be defined as the number of units of heat necessary to raise the temperature of 1 pound of that body 1° Fah.

When a substance is heated it expands, and its temperature is increased. It is evident, therefore, that heat is required both to raise the temperature and to increase the distance between the particles of the substance.

The heat used in the latter case is converted into interior work, and is not sensible to the thermometer; but it will be given out, if the temperature of the substance is reduced to the original point.

Thus, while heat is apparently lost, it is only stored up, ready to do work, and the substance possesses a certain amount of potential energy, or possibility of doing work.

Now, as different substances vary greatly in their molecular constitution, expanding and contracting the same amount with widely differing degrees of force, it is to be expected that the quantity of heat that will raise one substance to a given temperature may produce a less or greater degree of sensible heat to another; and we find in practice that such is the case.

The condition of heat is measured as a quantity, and its amounts in different bodies and under different circumstances are compared by means of the changes in some measurable phenomenon produced by its transfer or disappearance.

In so using changes of temperature, it is not to be taken for granted that equal differences of temperature in the same body correspond to equal quantities of heat. This is the case, indeed, for perfectly gaseous bodies; but that is a fact only known by experiment.

On bodies in other conditions, equal differences of temperature do not exactly correspond to equal quantities of heat. To ascertain, therefore, by an experiment on the changes of temperature of any given substances, what proportion two quantities of heat bear to each other, the only method which is of itself sufficient, in the absence of all other experimental data, is the comparison of the weights of that substance which are raised from the same low temperature to a high or fixed temperature.

The Unit of Heat.—The unit of heat, or thermal unit employed, is the quantity of heat, as before stated, that would raise 1 pound of pure water 1° Fah., or from 39° to 40° Fah.

The reason for selecting that part of the scale

which is nearest the temperature of the greatest density of water, is because the quantity of heat corresponding to an interval of one degree in a given weight of water is not exactly the same in different parts of the scale of temperature.

Latent Heat.—Latent heat means a quantity of heat which has disappeared, having been employed to produce some change other than elevation of temperature. By exactly reversing that change, the quantity of heat which had disappeared is reproduced.

When a body is said to possess or contain so much latent heat, what is meant is simply this: that the body is in a condition into which it was brought from a former different condition by transferring to it a quantity of heat which did not raise its temperature, the change of condition having been different from change of temperature, and that by restoring the body to its original condition in such a manner as exactly to reverse the former process. The quantity of heat formerly expended can be reproduced in the body and transferred to other bodies.

When a body passes from the solid to the liquid state, its temperature remains stationary, or nearly so, at a certain melting point, during the whole operation of melting, and in order to make that operation go on, a quantity of heat must be transferred to the substance melted, having a certain amount for each unit of weight of the substance. That heat does not raise the temperature of the substance, but disappears in causing its condition to change from the solid to the liquid state.

When a substance passes from the liquid to the solid state, its temperature remains stationary, or nearly so, during the whole operation of freezing; a quantity of heat equal to the latent heat of fusion is produced in the body, and in order that the operation of freezing may go on, that heat must be transferred from that body to some other substance.

Sensible Heat.—Sensible heat is that which is sensible to the touch or measurable by the thermometer.

Mechanical Equivalent of Heat.—The mechanical equivalent of heat is the amount of work performed by the conversion of one unit of heat into work. This has been determined to be equal in amount to the work required to raise 772 pounds one foot high, or one pound 772 feet high. And as heat and work are mutually convertible, if a body weighing one pound, after falling through a height of 772 feet, were to have its motion suddenly arrested, it would develop sufficient heat to raise the temperature of a pound of water one degree.

If a pound of water, at a temperature of 212° Fah., is converted into steam, the latter will have a volume of about 27¼ cubic feet. Now, suppose that the water is evaporated in a long cylinder, of exactly one foot cross section, open to the atmosphere at the

top. When all the water in the cylinder has disappeared, there will be a column of steam 27¼ feet high, which has risen to this height against the pressure of the atmosphere.

The pressure of the air being nearly 15 pounds per square inch, the pressure per square foot is 2,117 pounds; and the external work performed by the water, in changing to steam, will be an amount required to raise 2,117 pounds to a height of 27¼ feet, or about 57,688 foot-pounds.

Now, since 772 foot-pounds of work require one unit of heat, the external work will take up 57,688 divided by 772, equals 74.72 units of heat.

But it has been shown that the total number of units of heat required to change water into steam is about 968 (more accurately, 966.6). Hence the internal work will be equal to an amount developed by the conversion of 966.6 less 74.72, equals 891.88 units of heat into work, and this will equal 891.88, multiplied by 772, equals 688,531 foot-pounds.

Mechanical Theory of Heat.—The mechanical theory of heat is now generally adopted. It considers that heat and work are interchangeable, and on this theory can be explained what becomes of the latent heat. All solid bodies are supposed to be made up of molecules, which are not in contact, but are prevented from separating by a force called cohesion.

If a body is heated to a sufficient temperature, the force of expansion becomes equal to that of cohesion, and the body is liquefied; and if still more heat is applied, the force of expansion exceeds that of cohesion, and the liquid becomes a vapor.

But in each of these changes work is performed, and the heat that is supplied is converted into work.

For instance, if ice is at a temperature of 32°, and heat is applied, this is converted into the work that is developed in changing ice into water, and we say that heat becomes latent, and when water is at 212°, and we continue to apply heat; this is converted into the work that must be done in changing the water into steam.

Dynamic Equivalent of Heat.—It is a matter of ordinary observation that heat, by expanding bodies, is a source of mechanical energy; and conversely, that mechanical energy, being expanded either in compressing bodies or in friction, is a source of heat.

In all other cases in which heat is produced by the expenditure of mechanical energy, or mechanical energy by the expenditure of heat, some other change is produced besides that which is principally considered; and this prevents the heat and the mechanical energy from being exactly equivalent.

Power of Expansion by Heat.—When bodies expand, the molecules of which they are composed are pushed farther asunder by the oscillatory motion communicated to them. The heat may be described as entering the substance and immediately setting to

work to separate the particles. The power or energy it exerts to do this is immense.

Molecular or Atomic Force of Heat.—All molecules are under the influence of two opposite forces. The one, molecular attraction, tends to bring them together; the other, heat, tends to separate them; its intensity varies with its velocity of vibration. Molecular attraction is only exerted at infinitely small distances, and is known under the name of cohesion, affinity, and adhesion.

Total or Actual Heat.—When a substance, by the expenditure of energy in friction, is brought from a condition of total privation of heat to any particular condition as to heat. Then if we, from the total energy so expanded, subtract, first, the mechanical work performed by the action of the substance on external bodies, through changes of its volume, during such heating; secondly, the mechanical work due to mutual actions between the particles of the substance itself during such heating, the remainder will represent the energy which is employed in making the substance hot.

Communication of Heat.—Heat may be communicated from a hot body to a cold one in three ways—by radiation, conduction, and circulation.

The rapidity with which heat radiates varies, other things being equal, as the square of the temperature of the hot body in excess of the temperature of the cold one; so that a body, if made twice as hot, will lose a degree of temperature in one-fourth of the time; if made three times as hot, it will lose a degree of temperature in one-ninth of the time, and so on in all other proportions.

Transmission of Heat.—Tredgold and others have made experiments to ascertain the rate at which heat is transferred from metal to gases and from gases to metal. Other things being equal, it has been found that the rate of transference is as the difference of temperature. But in practice the conditions are different from those in the experiment; generally, in experiments, the air has been still, and the gases moving under natural draft; but in locomotive practice, the velocity of the gases is so great as to render the results of most experiments inapplicable.

Effects of Heat on the Circulation of Water in Boilers.—As the particles of water rise heated from the bottom of the boiler, other particles necessarily subside into their places, and it is a point of considerable importance to ascertain the direction in which the currents approach the plate to receive heat. A particle of water cannot leave the heated plate until there is another particle at hand to occupy its position; and, therefore, unless a due succession in the particles is provided for, the plate cannot get rid of its heat, and the proper formation of steam is hindered.

But it must be understood that vaporization does not depend on the quantity of heat applied to the

plate, but on the quantity of heat abstracted from it by the particles of water.

Medium Heat.—The medium heat of the globe is placed at 50°; at the torrid zone 75°; at moderate climates 50°; near the Polar regions 36° Fah.

The extremes of natural heat are from —70° to 120°; of artificial heat, from —166° to 36000° Fah.

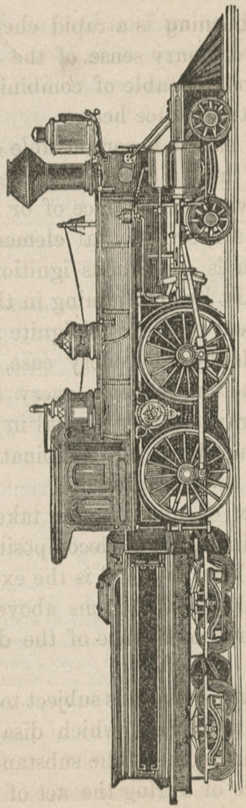
LATENT HEAT OF FUSION.

FLUIDS.	Fah.	VAPORS.	Fah.
Ice	142°	Steam	966.6°
Sulphur	168	Vinegar	875
Lead	9.8	Ammonia	860
Beeswax	176	Alcohol	372
Zinc	50.6	Ether	174

TABLE

SHOWING THE EFFECTS OF HEAT UPON DIFFERENT BODIES.

	Fah.		Fah.
Cast-iron, thoroughly smelted	2754°	Lead melts	608°
Fine gold melts	2282	Bismuth "	504
Fine silver "	1832	Tin "	446
Copper "	2160	Tin and Bismuth, equal parts, melt	286
Brass "	1900	Tin, 3 parts, Bismuth 5, and Lead 2 parts, melt	212
Red heat, visible by day	1077	Alcohol boils	174
Iron red-hot in twilight	884	Ether "	98
Common fire	790	Human blood (heat of)	98
Iron, bright red in the dark	752	Strong wine freezes	20
Zinc melts	680	Brandy "	7
Quicksilver boils	648	Mercury melts	—39
Linseed oil	600		



EIGHT-WHEEL PASSENGER LOCOMOTIVE.

The locomotive, from the date the first engine was placed on the track by the father of railroads, has a brighter record than any other branch of mechanical engineering.

COMBUSTION.

Combustion or burning is a rapid chemical combination. In the ordinary sense of the word, combustible means a body capable of combining rapidly with oxygen so as to produce heat.

No substance in nature is combustible of itself, to whatever degree of heat it may be exposed; nor can it be ignited only when in presence of or in mechanical mixture with air, or its vital element, oxygen, because combustion is continuous ignition, and can only be made to exist by maintaining in the combustible mixture the heat necessary to ignite it.

Chemical combination, in every case, is accompanied by a production of heat; every decomposition, by a disappearance of heat equal in amount to that which is produced by the combination of the elements which are to be separated.

When a complex chemical action takes place in which various combinations and decompositions occur simultaneously, the heat obtained is the excess of the heat produced by the combinations above the heat, which disappears in consequence of the decompositions.

Sometimes the heat produced is subject to a further deduction, on account of heat which disappears in melting or evaporating some of the substances which combine either before or during the act of combination.

Substances combine chemically in certain proportions only. To each of the substances known in chemistry, a certain number can be assigned, called its chemical equivalent, having these properties:—1st. That the proportions by weight in which substances combine chemically can all be expressed by their chemical equivalents, or by simple multiples of their chemical equivalents. 2d. That the chemical equivalent of a compound is the sum of the chemical equivalents of its constituents.

Chemical equivalents are sometimes called atomic weights or atoms, in accordance with the hypothesis that they are proportional to the weights of the supposed atoms of bodies, or smallest similar parts into which bodies are assumed to be divisible by known forces. The term *atom* is convenient from its shortness, and can be used to mean "chemical equivalent" without necessarily affirming or denying the hypothesis from which it is derived, and which, how probable soever it may be, is, like other molecular hypotheses, incapable of absolute proof.

The chief elementary combustible constituents of ordinary fuel are carbon and hydrogen. Sulphur is another combustible constituent of ordinary fuel, but its quantity is small and its heating power of no practical value.

Coal is composed, so far as combustion is concerned, of solid carbon and a gas consisting of hydrogen and carbon.

When the coal is heated, it first discharges its gas; the solid carbon left then ignites in presence of oxygen, and will retain the temperature necessary to combustion so long as oxygen is supplied.

The Ingredients of Fuel.—Fixed or free carbon which is left in the form of charcoal or coke after the volatile ingredients of the fuel have been distilled away. This ingredient burns either wholly in the solid or partly in the solid and partly in the gaseous state; the latter part being first dissolved by previously formed carbonic acid, as already explained.

Hydrocarbons, such as gas, pitch, tar, naphtha, etc., all of which must pass into the gaseous state before being burned. If mixed on their first issuing from among the burning carbon with a large quantity of air, these inflammable gases are completely burned, with a transparent blue flame, producing carbonic acid and steam.

Mixture of Fuel and Air.—In burning charcoal, coke, and coals which contain a small proportion only of hydrocarbons, a supply of air sufficient for complete combustion will enter from the ash-pit through the bars of the grate, provided there is a sufficient draught, and that care is taken to distribute the fresh fuel evenly over the fire, and in moderate quantities at a time.

Available Heat of Combustion.—The available heat of combustion of one pound of a given sort of fuel, is that part of the total heat of combustion which is communicated to the body, to heat which the fuel is burned.

Anthracite Coal. — The chemical composition of anthracite coal is similar to charcoal, from which it differs chiefly in its form, being very hard and compact, and in the greater quantity of ashes which it contains. It is, like charcoal, unaltered in form after exposure to the strongest heat; even after passing through a blast furnace it has equally as sharp edges, and is in form exactly as it was before.

COMPOSITIONS OF DIFFERENT KINDS OF ANTHRACITE COAL.

	Carbon.	Volatile matter.	Ashes.	Specific gravity.
Lehigh coal	88.50	7.50	4.00	1.61
Schuylkill coal	92.07	5.03	2.90	1.57
Pottsville	94.10	1.40	4.50	1.50
Pinegrove	79.57	7.15	3.28	1.54
Wilkesbarre	88.90	7.68	3.49	1.40
Carbondale	90.23	7.07	2.70	1.40

The analysis of anthracite shows good coal of that class to be composed of 90.45 carbon, 2.43 hydrogen, 2.45 oxygen, some nitrogen, and 4.67 ashes.

The ashes generally consist, like those of bituminous coal, of silex, alumina, oxide of iron, and chlorides, which generally evaporate and condense on cold objects in the form of white films.

Anthracite is not so inflammable as either dry wood or bituminous coal, but it may be made to burn quite as vividly as either, by exposing it to a strong draft, or in a large mass to the action of the air.

The Quantity of Air Required for the Combustion of Anthracite Coal.—In view of the quantity of oxygen required to unite chemically witn the various constituents of the coal, we find that in 100 pounds of anthracite coal, consisting of 91 per cent. of carbon and 9 per cent. of the other matter, it will be necessary to have 242.66 pounds of oxygen, since to saturate a pound of carbon by the formation of carbonic acid requires $2\frac{2}{3}$ pounds of oxygen. To saturate a pound of hydrogen in the formation of water, requires 8 pounds of oxygen; hence 3.46 pounds of hydrogen will take 27.68 pounds of oxygen for its saturation.

If then we add 242.66 pounds of oxygen for its saturation, 270.34 pounds of oxygen are required for the combustion of 100 pounds of coal.

A given weight of air contains nearly 23.32 per cent. of oxygen; hence to obtain 270.34 pounds of oxygen, we must have about four times that quantity of atmospheric air, or, more accurately, 1159.5 pounds of air for the combustion of 100 pounds of coal.

A cubic foot of air at ordinary temperatures weighs about .076 pounds; so that 100 pounds of coal require 15,254 cubic feet of air, or 1 pound of coal requires about 152 cubic feet of air, supposing every atom of the oxygen to enter into combination.

But as from one-third to one-half of the air passes unconsumed through the fire, an allowance of 240 cubic feet of air for each pound of coal will be a small enough allowance to answer the requirements of practice, and in some cases as much as 320 cubic feet will be required.

The Evaporative Efficiency of a Pound of Anthracite Coal. — The evaporative efficacy of a pound of carbon has been found, experimentally, to be equivalent to that necessary to raise 14,000 pounds of water through 1 degree, or 14 pounds of water through 1000 degrees, supposing the whole heat generated to be absorbed by the water.

Now, if the water be raised into steam from a temperature of 60°, then 1118.9° of heat will have to be imparted to it to convert it into steam of 15 pounds pressure per square inch; 14,000 divided by 1118.9 equals 12.5 pounds will be the number of pounds of water, therefore, which a pound of carbon can raise into steam of 15 pounds pressure from a temperature of 60°. This, however, is a considerably larger result than can be expected in practice.

Bituminous Coal. — Under this class we range all that mineral coal which forms coke, that is, it swells upon being exposed to heat, burns with a bright flame, blazes, and after the flame disappears there remains a spongy, porous mass — coke — which burns without flame like charcoal.

In its composition we find chiefly carbon, oxygen,

hydrogen, nitrogen, sulphur, and ashes, with a little water, which has been absorbed.

The following table shows the comparative composition of various sorts of mineral fuel:

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ashes.
Turf	58.09	5.93	31.37	4.61
Brown Coal	71.71	4.85	21.67	1.77
Hard Bituminous Coal	82.92	6.49	10.86	0.13
Cannel Coal	83.75	5.66	8.04	2.55
Cooking or Baking Coal	87.95	5.24	5.41	1.40
Anthracite	91.98	3.92	3.16	0.94

An essential condition in forming coke is that the coal, on being heated, swells and changes into irregular spongy masses, which adhere intimately together. This operation is designed to expel sulphur and hydrogen, and form a coal which is not altered by heat. The sulphur cannot be entirely separated from coke, or from carbon, no matter how high the heat may be; neither can all the hydrogen be removed from carbon by simply heating the compound. If oxygen is admitted to these combinations, both sulphur and hydrogen may be almost entirely expelled, that is, provided the oxygen is not introduced under too high or too low a heat.

The most important point, and one which has a direct bearing upon the value of coal, is the quantity of heat which it can evolve in combustion.

If we assume that the quantity of ashes is equal in the four substances mentioned below, that is, 5 per cent. in each, and suppose further that pine charcoal furnishes 100 parts of heat, the following table shows the quantity which must be liberated in their perfect combustion.

Kind of Coal.	Carbon.	Hydrogen.	Water.	Quality of Heat.
Brown Coal..............	69	3	23	78
Cooking Coal..........	75	4	16	87
" "	78	4	13	90
Anthracite Coal........	85	3	7	94
Pure Carbon............	100	...	...	100

Bituminous coal, like all other fuel, is a compound substance, which may be decomposed by heat into several distinct elements — generally five or six at least. So far as relates to combustion, we are concerned principally with but two of these, viz., solid carbon, represented by coke, and hydrogen, generally known under the indefinite term of "gas." These two elements contain principally the full heating qualities of the coal. The carbon, so long as it remains as such, is always solid and visible.

The hydrogen, when driven from the coal by heat, carries with it a portion of carbon, the gaseous compound being known as carburetted hydrogen.

A ton of 2,000 pounds of average bituminous coal contains, say 1,600 pounds, or 80 per cent. of carbon.

100 pounds, or 5 per cent. of hydrogen, and 300 pounds, or 15 per cent. of oxygen, nitrogen, sulphur, sand and ashes.

But if this coal be coked, the 100 pounds of hydrogen driven off by heat will carry about 300 pounds of carbon in combination with it, making 400 pounds, or nearly 10,000 cubic feet of carburetted hydrogen gas.

But still 1,300 pounds of carbon (65 per cent. of the original coal) will be left, and, with the earthy matter, ashes, sulphur, etc., retained with it, the coke will weigh but about 1,350 or 1,400 pounds, — 67½ to 70 per cent. of the original coal.

The only proportions in which carbon and hydrogen combine with air in combustion are these:

For every pound of carbon (pure coke), 11½ pounds (equal to 152 cubic feet) of air are required to combine intimately with it.

For every pound of hydrogen, 35 pounds (equal to 457 cubic feet) of air are required to be similarly combined.

Thus for every pound of carburetted hydrogen gas, being one-fourth pound of hydrogen and three-fourths of a pound of carbon, 17⅝ pounds (equal to 228 cubic feet) of air are required to be combined with it.

These are the elements and their combining proportions that have to be dealt with in a LOCOMOTIVE FURNACE. For every 2,000 pounds of coal burned, the 400 pounds of carburetted hydrogen — the "gas" —

require 91,200 cubic feet of atmospheric air at ordinary temperature, and the 1,300 pounds of solid carbon require 197,600 cubic feet of air. Practically, the "gas" from a ton of ordinary bituminous coal requires 100,000 cubic feet of air for its combustion, while the remaining coke requires 200,000 feet. Thus the gaseous matter of the coal requires one-half as much air as is taken up by the solid coke.

The heating value of any combustible is exactly proportional to the quantity of air with which it will combine in combustion. Hence hydrogen, which combines with three times the quantity of air (oxygen) which would be taken up by carbon, has, for equal weights, three times the heating value. Thus, the 100 pounds of pure hydrogen in a ton of coal have the same heating efficiency as that due to 300 pounds of the remaining carbon or pure coke.

It will now be seen that complete combustion cannot produce smoke, since smoke contains a quantity of unburnt matter, and is in itself a proof of incomplete combustion. The products of perfect combustion are invisible — being for carbon and oxygen, carbonic acid; and for hydrogen and oxygen, invisible steam, which condenses into water.

The admission of heated air to furnaces or fire-boxes of locomotives can be of no practical value, since for every 461° Fah. of heat added, its original bulk or volume is doubled; trebled at 922° Fah.; so that at 2305° Fah. the heated air in the interior

of the furnace has six times its original volume. This makes it more unmanageable, and as its contained oxygen remains the same in weight, its mixture with the gas becomes more difficult, while, when mixed, it can do only the same work as before.

Waste of Unburnt Fuel.—This generally arises from the brittleness of the fuel, combined with want of care on the part of the fireman, by which cause the fuel is made to fall into small pieces, which escape between the grate-bars into the ash-pit, and are lost.

It is almost impossible to estimate the loss of fuel occasioned by carelessness and bad firing, but the amount which is unavoidable, even with care and good firing, has been ascertained by experiment to range from 2½ to 3 per cent. of the fuel consumed.

Spontaneous Combustion. — A great deal has been said and written on the subject of spontaneous combustion, and the danger likely to result from allowing steam-pipes to come in contact with the wood-work in buildings; but as the temperature of superheated steam only ranges from 300° to 500° Fah., it is only able to set fire to such substances as sulphur, gun-cotton, and nitro-glycerine. It is, perhaps, able to fire gunpowder, but certainly cannot ignite wood.

It is only when dried wood, sawdust, or rags have been saturated by drying oil or other equivalents, that the temperature may be indefinitely raised, and finally reach 400° or 500° Fah., or until the point of inflammability is attained. This is caused by the oxidation of the oil and the agency of the air.

Fire.—Fire is one of the elements which has always attracted a great deal of attention from natural philosophers, and many theories have been advanced to account for all the remarkable phenomena which accompany heat. Late investigations, however, have proved that combustion is the result of chemical changes in bodies.

TABLE

SHOWING THE TOTAL HEAT OF COMBUSTION OF VARIOUS FUELS.

SORT OF FUEL.	Equivalent in pure carbon.	Evaporative power in lbs. water from 212° Fah.	Total heat of combustion in lbs. water heated 1° Fah.
Charcoal	0.93	14.00	13500
Charred peat	0.80	12.00	11600
Coke—good	0.94	14.00	13620
" mean	0.88	13.20	12760
" bad	0.82	12.30	11890
COAL.			
Anthracite	1.05	15.75	15225
Hard bituminous—hardest.	1.06	15.90	15370
" " softest..	0.95	14.25	13775
Cooking coal	1.07	16.00	15837
Canning coal	1.04	15.60	15080
Long flaming splint coal....	0.91	13.65	13195
Lignite	0.81	12.15	11745
PEAT.			
Perfectly air-dry	0.66	10.00	9660
Containing 25 per ct. water	......	7.25	7000
WOOD.			
Perfectly air-dry	0.50	7.50	7245
Containing 20 per ct. water	......	5.80	5600

TABLE

OF TEMPERATURES REQUIRED FOR THE IGNITION OF DIFFERENT COMBUSTIBLE SUBSTANCES.

SUBSTANCES.	Temperature of Ignition.	REMARKS.
Phosphorus	140°	Melts at 112°.
Bisulphide of carbon vapor	300°	Melts at 130°.
Fulminating Powder	374°	Used in percussion caps.
Fulminate of Mercury	392°	According to Legue and Champion.
Equal parts of chlorate of potash and sulphur	395°	
Sulphur	400°	Melts, 239°; boils, 570°.
Gun-cotton	428°	According to Legue and Champion.
Nitro-glycerine	494°	" " "
Rifle-powder	550°	" " "
Gunpowder, coarse	563°	" " "
Picrate of mercury, lead or iron	565°	" " "
Picrate powder for torpedoes	570°	" " "
Picrate powder for muskets	576°	" " "
Charcoal, the most inflammable willow used for gunpowder	580°	According to Pelouse and Fremy.
Charcoal made by distilling wood at 500°	660°	" " "
Charcoal made at 600°	700°	" " "
Picrate powder for cannon	716°	
Very dry wood, pine	800°	
" " " oak	900°	
Charcoal made at 800°	900°	

It will be seen by the above table that the most combustible substances generally considered very dangerous, will only ignite by heat alone at a high temperature, so that for their prompt ignition it requires the actual contact of a spark.

GASES.

All substances, whether animal, vegetable, or mineral, consisting of carbon, hydrogen, and oxygen, when exposed to a red heat, produce various inflammable elastic fluids, capable of furnishing artificial light. We perceive the evolution of this elastic fluid during the combustion of coal in a common fire.

Bituminous coal, when heated to a certain degree, swells and kindles and frequently emits remarkably bright streams of flame, and after a certain period these appearances cease, and the coal glows with a red light.

The flame produced from coal, oil, wax, tallow, or other bodies which are composed of carbon and hydrogen, proceeds from the production of carburetted hydrogen gas, evolved from the combustible body when in an ignited state.

If coal, instead of being burnt in the way now stated, is submitted to a temperature of ignition in close vessels, all its immediate constituent parts may be collected. The bituminous part is distilled over in the form of coal-tar, etc., and a large quantity of an aqueous fluid is disengaged at the same time, mixed with a portion of essential oil and various ammoniacal salts.

A large quantity of carburetted hydrogen, carbonic oxide, carbonic acid, and sulphuretted hydrogen also make their appearance, together with small quantities

of cyanogen, nitrogen, and free hydrogen; and the fixed base of the coal alone remains behind in the distillatory apparatus, in the form of a carbonaceous substance called coke. An analysis of the coal is thus effected by the process of destructive distillation.

Hydrogen.—Hydrogen is the lightest of all known gases, its specific gravity being only 0.06896, air being 1. This gas is colorless, and when perfectly pure, inodorous. It has a powerful affinity for oxygen, and is therefore eminently combustible. Intense heat is developed by the combustion of hydrogen in oxygen gas, and but little light.

Carbon.—Carbon is well known under the form of coke, charcoal, lamp-black, etc. It is one of the principal constituents of all varieties of coal, and is the basis of the illuminating gases. Carbonic oxide is a colorless and inodorous gas, rather lighter than common air, having a specific gravity of 0.9727, is sparingly absorbed by water, and does not precipitate lime-water. It is inflammable, burning with a blue flame; the product of its combustion is carbonic acid.

Carbon unites with hydrogen in many proportions, and many of these compounds are produced during the distillation of coal; but the only two of importance are carburetted hydrogen and olefiant gas.

Carburetted Hydrogen.—Carburetted hydrogen is abundantly formed in nature, in stagnant pools, ditches, etc., wherever vegetables are undergoing the process of putrefaction; it also forms the greater part of the gas obtained from coal. Carburetted hydrogen consists of 100 volumes of vapor of carbon, and 200 of hydrogen. It is colorless and almost inodorous; it is not dissolved to any extent by water, and is much lighter than atmospheric air, its density being 0.5527. It is very inflammable, burning with a strong yellow flame. The products of its combustion are carbonic acid and water.

Carburetted hydrogen, or coal-gas, when freed from the obnoxious foreign gases, may be propelled in streams out of small apertures, which, when lighted, form jets of flame, which are called gas-lights.

Olefiant Gas. — Olefiant gas is a product of the distillation of oil, resin, and also of coal, when the process is well conducted. It is colorless, tasteless, and without smell when pure. Water dissolves about one-eighth of its bulk of this gas. It is formed of two volumes of hydrogen, and two of the vapor of carbon condensed into one volume.

Olefiant gas burns with an intense white light, and requires a larger portion of oxygen for its combustion, one volume of the gas requiring not less than three volumes of pure oxygen, or fifteen volumes of atmospheric air for decomposition. The products of the combustion are water and carbonic acid.

Nitrogen. — Nitrogen is one of the constituents of coal. It has the properties of extinguishing burning bodies, and is not absorbed by water; its specific gravity is 0.9760, being lighter than common air, of which it forms a constituent part.

Liquefaction of Gases. — Many of the gases have already been brought into the liquid state by the conjoint agency of cold and compression, and all of them are probably susceptible of a similar reduction by the use of means sufficiently powerful for the required end.

They must consequently be regarded as the superheated steams or vapors of the liquids into which they are compressed.

Compression and Dilatation of Gases. — When a gas or vapor is compressed into half its original bulk, its pressure is double; when compressed into a third of its original bulk, its pressure is treble; when compressed into a fourth of its original bulk, its pressure is quadrupled; and generally the pressure varies inversely as the bulk into which the gas is compressed.

So in like manner if the volume be doubled, the pressure is made one-half of what it was before — the pressure being in every case reckoned from 0, or from a perfect vacuum.

Thus, if we take the average pressure of the atmosphere at 14.7 pounds on the square inch, a cubic foot of air, if suffered to expand into twice its bulk by being placed in a vacuum measuring two cubic feet, will have a pressure of 7.35 pounds above a perfect vacuum, and also of 7.35 pounds below the atmospheric pressure; whereas, if the cubic foot be compressed into a space of half a cubic foot, the pressure will become 29.4 pounds above a perfect vacuum, and 14.7 pounds above the atmospheric pressure.

The specific gravity of any one gas to that of another will not exactly conform to the same ratio under different degrees of heat and other pressures of the atmosphere

STEAM.

The elastic fluid into which water is converted by the continued application of heat.

All liquids whatever, when exposed to sufficiently high temperature, are converted into vapor.

The mechanical properties of vapor are similar to those of gases in general. The property which is most important to be considered, in the case of steam, is the elastic pressure. When a vapor or gas is contained in a close vessel, the inner surface of the vessel will sustain a pressure arising from the elasticity of the fluid.

This pressure is produced by the mutual repulsion of the particles, which gives them a tendency to fly asunder, and causes the mass of the fluid to exert a force tending to burst any vessel within which it is confined. This pressure is uniformly diffused over every part of the surface of the vessel in which such a fluid is contained; it is to this quality that all the mechanical power of steam is due.

Steam might be said to be the result of a combination of water with a certain amount of heat, and the expansive force of steam arises from the absence of cohesion between and among the particles of water.

Heat universally expands all matter within its influence, whether solid or fluid. But in a solid body it has the cohesion of the particles to overcome, and this so circumscribes its effect that in cast-iron, for instance, a rate of temperature above the freezing-point sufficient to melt it causes an extension of only about one-eighth of an inch in a foot. With water, however, a temperature of 212°, or 180° above the freezing-point (and which is far from a red heat), converts it into steam of 1,700 times its original bulk or volume.

Steam cannot mix with air while its pressure exceeds that of the atmosphere, and it is this property, with that which makes the condition of a body dependent on its temperature, that explains the condensing property of steam.

In a cylinder once filled with steam of a pressure of 15 pounds or more to the square inch, all air is excluded.

Now, as the existence of the steam depends on its temperature, by abstracting that temperature (which may be done by immersing the cylinder in cold water or cold air) the contained steam assumes the state due to the reduced temperature, and this state will be water.

But one of the most noteworthy properties of steam is its latent or concealed heat. The latent heat of steam, though showing no effect on the thermometer, may be as easily known as the sensible or perceivable heat.

To show this property of steam by experiment, place an indefinite amount of water in a closed vessel, and let a pipe, proceeding from its upper part, communicate with another vessel, which should be open, and, for convenience of illustration, shall contain just 5.37 pounds of water at 32°, or just freezing. The pipe from the closed vessel must reach nearly to the bottom of the open one. By boiling the water contained in the first vessel until steam enough has passed through the pipe to raise the water in the open vessel to the boiling-point (212° Fah.), we shall find the weight of the water contained by the latter to be 6½ pounds. Now, this addition of one pound to its weight has resulted solely from the admission of steam to it, and this pound of steam, therefore, retaining its own temperature of 212°, has raised 5.37 pounds of water 180°, or an equivalent to 966.6°, and including its own temperature, we have 1178.6°, which it must have possessed at first.

The sum of the latent and sensible heat of steam is in all cases nearly constant, and does not vary much from 1200°.

The elasticity of steam increases with an increase in the temperature applied, but not in the same ratio. If steam is generated from water at a temperature which gives it the same pressure as the atmosphere, an additional temperature of 38° will give it the pressure of two atmospheres ; a still further addition of 42° gives it the tension of four atmospheres

and with each successive addition of temperature of between 40° and 50° the pressure becomes doubled.

An established relation must exist between the temperature and elasticity of steam ; in other words, water at 212° Fah. must be under the pressure of the steam naturally resulting from that temperature, and so at any other temperature.

If this natural pressure on the surface of the water be removed without a corresponding reduction in the temperature, a violent ebullition of the water is the immediate result.

Another result attending formation of steam is, that when an engine is in operation and working off a proper supply of steam, the water level in the boiler artificially rises, and shows by the gauge-cocks a supply greater than that which really exists.

As the pressure of steam is increased the sensible heat is augmented, and the latent heat undergoes a corresponding diminution, and *vice versa.* The sum of the sensible and latent heat is, in fact, a constant quantity ; the one being always increased at the expense of the other.

It has been shown that in converting water at 32° of temperature, and under a pressure of 15 pounds per square inch, it was necessary first to give it 180° additional sensible heat, and afterwards 966.6° of latent heat, the total heat imparted to it being 1146.6°. Such, then, is the actual quantity of heat which must be imparted to ice-cold water to convert it into steam. The actual temperature to which water would be raised by the heat necessary to evaporate it, if its evaporation could be prevented by confining it in a close vessel, will be found by adding 32° to 1146.6°.

It may, therefore, be stated that the heat necessary for the evaporation of ice-cold water is as much as would raise it to the temperature of 1178.6°, if its evaporation were prevented.

If tne temperature of red-hot iron be, as it is supposed, 800° or 900°, and that all bodies become incandescent at the same temperature, it follows that to evaporate water it is necessary to impart to it 400° more heat than would be sufficient to render it red-hot, if its evaporation were prevented.

It has been asserted, in some scientific works, that by mere mechanical compression, steam will be converted into water. This is, however, an error, since steam, in whatever state it may exist, must possess at least 212° of heat; and as this quantity of heat is sufficient to maintain it in the vaporous form under whatever pressure it may be placed, it is clear that no compression or increase of pressure can diminish the actual quantity of heat contained in the steam, and it cannot, therefore, convert any portion of the steam into power.

Steam, by mechanical pressure, if forced into a diminished volume, will undergo an augmentation both of temperature and pressure, the increase of

temperature being greater than the diminution of volume; in fact, any change of volume which it undergoes will be attended with the change of temperature and pressure indicated in the table on pages 91, 92.

The steam, after its volume has been changed, will assume exactly the pressure and temperature which it would have in the same volume if it were immediately evolved from water.

Now, let us suppose a cubic inch of water converted into steam under a pressure of 15 pounds per square inch, and the temperature of 212°. Then let its volume be reduced by compression in the proportion of 1700 to 930. When so reduced, its temperature will be found to have risen from 15 pounds per square inch to 29½ pounds per square inch; but this is exactly the state as to pressure, temperature, and density the steam would be in if it were immediately raised from water under the pressure of 29½ pounds per square inch. It appears, therefore, that in whatever manner, after evaporation, the density of steam be changed, whether by expansion or contraction, it will still remain the same as if it were immediately raised from water in its actual state.

The circumstance which has given rise to the erroneous notion that mere mechanical compression will produce a condensation of steam, is that the vessel in which steam is contained must necessarily have the same temperature as the steam itself.

Water while passing into steam suffers a great enlargement of volume; steam, on the other hand, in being converted into water, undergoes a corresponding diminution of volume. It has been seen that a cubic inch of water, evaporated at the temperature of 212°, swells into 1700 cubic inches of steam. It follows, therefore, that if a closed vessel, containing 1700 cubic inches of such steam, be exposed to cold sufficient to take from the steam all its latent heat, the steam will be reconverted into water, and will shrink into its original dimensions, and will leave the remainder of the vessel a vacuum.

This property of steam has supplied the means, in practical mechanics, of obtaining that amount of mechanical power which the properties of the atmosphere confer upon a vacuum.

The temperature and pressure of steam produced by immediate evaporation, when it has received no heat, save that which it takes from the water, have a fixed relation one to the other.

If this relation was known and expressed by a mathematical formula, the temperature might always be inferred from the pressure, or *vice versa*.

But physical science has not yet supplied any principle by which such a formula can be deduced from any known properties of liquids.

The same difficulty which attends the establishment of a general formula expressing the relation between the temperatures and pressures of steam,

also attends the determination of one expressing the relation between the pressure and the augmented volume into which the water expands by evaporation.

In the preceding observations, steam has been considered as receiving no heat except that which it takes from the water during the process of evaporation; the amount of which, as has been shown, is 1146.6° more than the heat contained in ice-cold water. But steam, after having been formed from water by evaporation, may, like all other material substances, receive an accession of heat from any external source, and its temperature may thereby be elevated.

If the steam to which such additional heat is imparted be so confined as to be incapable of enlarging its dimensions, the effect produced upon it by the increase of temperature will be an increase of pressure.

But if, on the other hand, it be confined under a given pressure, with power to enlarge its volume, subject to the preservation of that pressure, as would be the case if it were contained in a cylinder under a movable piston loaded with a given pressure, then the effect of the augmented temperature will be, not an increase of pressure, but an increase of volume; and the increase of volume in this latter case will be in exactly the same proportion as the increase of pressure in the former case.

These effects of elevated temperature are common, not only to the vapors of all liquids, but also to all permanent gases; but, what is much more remarkable, the numerical amount of the augmentation of pressure or volume produced by a given increase of temperature is the same for all vapors and gases. If the pressure which any gas or vapor would have, were it reduced to the temperature of melting ice, be expressed by 100,000, the pressure which it will receive for every degree of temperature by which it is raised will be expressed by 208⅓, or what amounts to the same, the additional pressure produced by each degree of temperature will be the 480th part of its pressure at the temperature of melting ice.

Steam which thus receives additional heat after its separation from the water from which it is evolved has been called *superheated steam*, to distinguish it from *common steam*, which is that usually employed in *steam engines*.

Steam of atmospheric pressure occupies 1642 times the volume of the water from which it is raised, and as a cubic foot of water weighs 62.4 pounds, a cubic foot of steam of atmospheric pressure weighs about .038 pound. In order to exert a pressure by its mere dead weight of 14.7 pounds per square inch, such steam of uniform density would have to stand at a height of 10½ miles.

Superheated steam admits of losing a part of its heat without suffering partial condensation; but *common* steam is always partially condensed, if any portion of heat be withdrawn from it.

TABLE

SHOWING THE VELOCITY WITH WHICH STEAM OF DIFFERENT PRESSURES WILL FLOW INTO THE ATMOSPHERE OR INTO STEAM OF LOWER PRESSURE.

Pressure above the atmosphere.	Velocity of escape per second.	Pressure above the atmosphere.	Velocity of escape per second.
Pounds.	Feet.	Pounds.	Feet.
1	540	50	1,736
2	698	60	1,777
3	814	70	1,810
4	905	80	1,835
5	981	90	1,857
10	1,232	100	1,875
20	1,476	110	1,889
30	1,601	120	1,900
40	1,681	130	1,909

One cubic foot of steam at a pressure of 15 pounds per square inch weighs .0367 pound.

Five cubic feet of steam at a pressure of 75 pounds per square inch weighs 1 pound.

Seventy-five cubic feet of steam at a pressure of 140 pounds per square inch weighs 26 pounds.

Rule for finding the Superficial Feet of Steam-pipe required to Heat any Building with Steam.

One superficial foot of steam-pipe to 6 superficial feet of glass in the windows, or 1 superficial foot of steam-pipe for every 100 square feet of wall, roof or ceiling, or 1 square foot of steam-pipe to 80 cubic feet of space; 1 cubic foot of boiler is required for every 1,500 cubic feet of space to be warmed.

The following table shows that the saving of fuel is in proportion to the increase of pressure — the advantage of generating and using high-pressure steam is thereby made apparent. The table also shows that the last 10 pounds of additional pressure only requires four degrees of heat to raise it; whereas the first 10 pounds of pressure above the atmosphere requires 29 additional degrees of heat to raise it a difference of 25 degrees.

Hence a small accession of heat at a high temperature produces an increase of elastic force; and a small abstraction of heat reduces its bulk, by the application of cold in the ratio of its density; proving the advantage of clothing cylinders, steam-pipes, boilers, etc., with a non-conductor of heat or cold — a sure saving of fuel, where adopted, and more particularly required where high-pressure steam is used.

Steam, at any given pressure, always stands at a certain temperature, which is termed the "temperature due to the pressure." Steam follows very nearly the same law that all other gaseous bodies are subject to in acquiring additional degrees of heat. The law is, briefly, as follows: That all gaseous bodies expand equally for equal additions of temperature; and that the progressive rate of expansion is equal for equal increments of temperature.

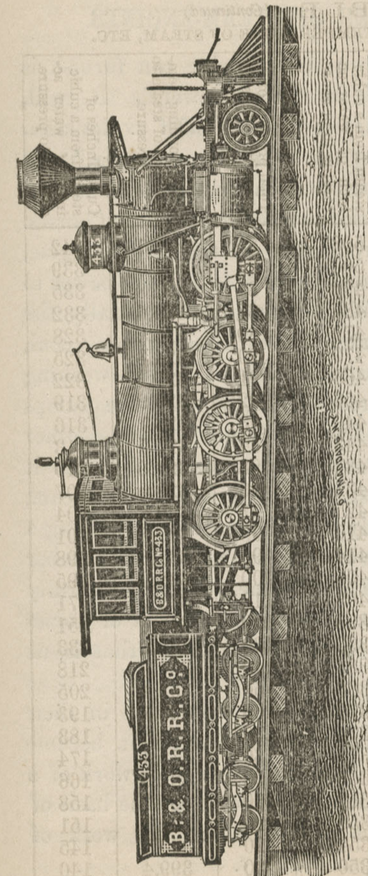
TABLE

SHOWING THE TEMPERATURE OF STEAM AT DIFFERENT PRESSURES FROM 1 POUND PER SQUARE INCH TO 240 POUNDS, AND THE QUANTITY OF STEAM PRODUCED FROM A CUBIC INCH OF WATER, ACCORDING TO PRESSURE.

Total pressure of steam in pounds per square inch.	Corresponding temperature of steam to pressure.	Cubic inches of steam from a cubic inch of water according to pressure.	Total pressure of steam in pounds per square inch.	Corresponding temperature of steam to pressure.	Cubic inches of steam from a cubic inch of water according to pressure
1	102.9	20868	28	247.6	941
2	126.1	10874	29	249.6	911
3	141.0	7437	30	251.6	883
4	152.3	5685	31	253.6	857
5	161.4	4617	32	255.5	833
6	169.2	3897	33	257.3	810
7	175.9	3376	34	259.1	788
8	182.0	2983	35	260.9	767
9	187.4	2674	36	262.6	748
10	192.4	2426	37	264.3	729
11	197.0	2221	38	265.9	712
12	201.3	2050	39	267.5	695
13	205.3	1904	40	269.1	679
14	209.1	1778	41	270.6	664
15	212.8	1669	42	272.1	649
16	216.3	1573	43	273.6	635
17	219.6	1488	44	275.0	622
18	222.7	1411	45	276.4	610
19	225.6	1343	46	277.8	598
20	228.5	1281	47	279.2	586
21	231.2	1225	48	280.5	575
22	233.8	1174	49	281.9	564
23	236.3	1127	50	283.2	554
24	238.7	1084	51	284.4	544
25	241.0	1044	52	285.7	534
26	243.3	1007	53	286.9	525
27	245.5	973	54	288.1	516

TABLE—(*Continued*)
SHOWING THE TEMPERATURE OF STEAM, ETC.

Total pressure of steam in pounds per square inch.	Corresponding temperature of steam to pressure.	Cubic inches of steam from a cubic inch of water according to pressure.	Total pressure of steam in pounds per square inch.	Corresponding temperature of steam to pressure.	Cubic inches of steam from a cubic inch of water according to pressure.
55	289.3	508	85	320.1	342
56	290.5	500	86	321.0	339
57	291.7	492	87	321.8	335
58	292.9	484	88	322.6	332
59	294.2	477	89	323.5	328
60	295.6	470	90	324.3	325
61	296.9	463	91	325.1	322
62	298.1	456	92	325.9	319
63	299.2	449	93	326.7	316
64	300.3	443	94	327.5	313
65	301.3	437	95	328.2	310
66	302.4	431	96	329.0	307
67	303.4	425	97	329.8	304
68	304.4	419	98	330.5	301
69	305.4	414	99	331.3	298
70	306.4	408	100	332.0	295
71	307.4	403	110	339.2	271
72	308.4	398	120	345.8	251
73	309.4	393	130	352.1	233
74	310.3	388	140	357.9	218
75	311.2	383	150	363.4	205
76	312.2	379	160	368.7	193
77	313.1	374	170	373.6	183
78	314.0	370	180	378.4	174
79	314.9	366	190	382.9	166
80	315.8	362	200	387.3	158
81	316.7	358	210	391.5	151
82	317.6	354	220	395.5	145
83	318.4	350	230	399.4	140
84	319.3	346	240	403.1	134



ANTHRACITE COAL-BURNING FREIGHT LOCOMOTIVE.

(Consolidation pattern.)

The above cut represents an anthracite coal-burning freight locomotive, built by the Danforth Locomotive Works for the B. & O. R.R., with four pair of drivers and swing truck. Diam. of cylinder, 20 in.; stroke, 24 in.; diam. of drivers, 50 in.; revolutions per minute, 81; area of piston, 314.16; travel of piston, 324; boiler pressure, 120 lbs.; maximum pressure in cylinder, 80 lbs.

$$\frac{314.16 \times 80 \times 81 \times 4 \times 2}{33,000} = 493.4 \text{ horse-power.}$$

HORSE-POWER OF STEAM-ENGINES.

The power which a steam-engine can furnish is generally expressed in "horse-power." It will, therefore, be necessary to make a brief explanation of what is meant by the term "horse-power," and how it has happened that the power of a steam-engine is thus expressed in reference to that of horses.

Prior to the introduction of the steam-engine, horses were very generally used to furnish power to perform various kinds of work, and especially the work of pumping water out of mines, raising coal, etc. For such purposes, several horses working together were required. Thus, to work the pumps of a certain mine, five, six, seven, or some other number of horses were found necessary. When it was proposed to substitute the new power of steam, the proposal naturally took the form of furnishing a steam-engine capable of doing the work of the number of horses used at the same time. Hence, naturally followed the usage of stating the number of horses which a particular engine was equal to, that is, its "horse-power."

But as the two powers were only alike in their equal capacity to do the same work, it became necessary to refer in both powers to some work of a similar character which could be made the basis of comparison. Of this character was the work of raising a weight perpendicularly.

A certain number of horses could raise a certain weight, as of coal out of a coal mine, at a certain speed; a steam-engine, of certain dimensions and supply of steam, could raise the same weight at the same speed. Thus, the weight raised at a known speed could be made the common measure of the two powers. To use the common measure it was necessary to know what was the power of one horse in raising a weight at a known speed.

By observation and experiment it was ascertained that, referring to the average of horses, the most advantageous speed for work was at the rate of 2½ miles per hour — that, at that rate, he could work 8 hours per day, raising perpendicularly from 100 to 150 pounds. The higher of these weights was taken by Watt, that is, 150 pounds at 2½ miles per hour. But this fact can be expressed in another form: — 2½ miles per hour is 220 feet per minute. So, the power of a horse was taken at 150 pounds, raised perpendicularly, at the rate of 220 feet per minute. This also can be expressed in another form: — The same power which will raise 150 pounds 220 feet high each minute, will raise

300 pounds	110	feet	high	each	minute.
3,000 "	11	"	"	"	"
33,000 "	1	"	"	"	"

For in each case the total work done is the same, viz., same number of pounds raised one foot in one minute.

It will be clearly perceived that 33,000 pounds, raised at the rate of one foot high in a minute, is the equivalent of 150 pounds at the rate of 220 feet per minute (or 2½ miles per hour); and it will be fully understood how it is that 33,000 pounds, raised at the rate of one foot per minute, expresses the power of one horse, and has been taken as the standard measure of power.

It has thus happened that the mode of designating the power of a steam-engine has been by "horse-power," and that one horse-power, expressed in pounds raised, is a power that raises 33,000 pounds one foot each minute. This unit power is now universally received. Having a horse-power expressed in pounds raised, it was easy to state the power of a steam-engine in horse-power, which was done in the following manner:

The force with which steam acts is usually expressed in its pressure in pounds on each square inch. The piston of a high-pressure steam-engine is under the action of the pressure of steam from the boiler, on one side of the piston, and of the back action of the pressure due to the discharging steam, on the other side.

The Power of the Engine.—The difference between the two pressures is the effective pressure on the piston; and the power developed by the motion of the piston, under this pressure, will be according to the number of square inches acted on and the speed

per minute which the piston is assumed to move. Thus, let the number of square inches in the area of the piston of a steam-engine be 100, the effective pressure on each square inch be 60 pounds, and the movement of the piston be at the rate of 300 feet per minute, then the total effective pressure on the piston will be $100 \times 60 = 6{,}000$ pounds, and the movement being 300 feet per minute, the piston will move with a power equal to raising 1,800,000 pounds one foot high each minute, (as $6{,}000 \times 300$ is 1,800,000,) and as each 33,000 pounds raised one foot high is one-horse power, then the power of the engine is 54-horse.

Now, if this power is used to do work, a part of it will be expended in overcoming the friction of the parts of the engine and of the machinery through which the power is transmitted to perform the work. The calculation made refers to the total power developed by the movement of the piston under the pressure of steam.

The number of feet travelled by the piston each minute is known from the length of the stroke of the piston in feet, and number of revolutions of engine per minute, there being two strokes of the piston for each revolution of the engine. When these three facts are known, the power of an engine can be readily and accurately ascertained, and it is evident that, without the knowledge of each of the facts, viz., square inches of piston, effective pressure on each square inch, and movement of piston per minute, the power cannot be known.

If it becomes necessary to state the power of an engine, then the three facts named above, viz., number of square inches of piston, effective pressure per square inch per stroke of piston, and speed of piston must be known or assumed, and when known or assumed, the horse-power can in that case be ascertained, as explained above.

There are three kinds of horse-power referred to in connection with the steam-engine—nominal, indicated, and actual.

The nominal horse-power is a power that raises 33,000 pounds one foot high each minute, or 150 pounds 220 feet high in the same space of time.

The indicated horse-power designates the total unbalanced power of an engine employed in overcoming the combined resistance of friction and the load. Hence it equals the quantity of work performed by the steam in one minute.

The actual or net horse-power expresses the total available power of an engine, hence it equals the indicated horse-power less an amount expended in overcoming the friction. The latter has two components, viz., the power required to run the engine, detached from its load, at the normal speed, and that required when it is connected with its load. For instance, if a person desires an engine to drive ten machines, each requiring ten-horse power the engine

should be of sufficient size to furnish one hundred *net* horse-power; but to produce this would require about one hundred and fifteen *indicated* horse-power.

Stationary Engines in the United States in 1870.—Whole number of stationary engines in the United States in 1870 was 40,191, with an aggregate horse-power of 1,215,711.

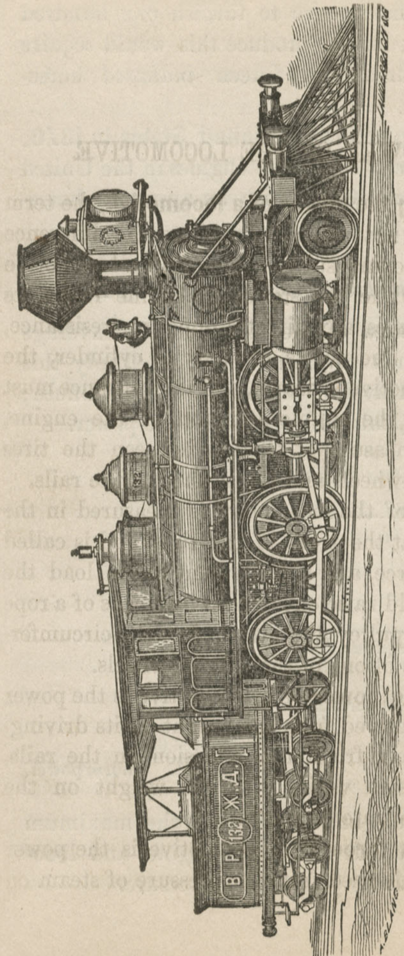
Rule for finding the Horse-power of Stationary Engines.

Multiply the area of the piston by the average pressure in pounds per square inch; multiply this product by the travel of piston in feet per minute; divide by 33,000, this will give the horse-power.

EXAMPLE.

Diameter of cylinder...............	12
	12
	144
	7854
Area of piston.......................	113.0976
Pressure, 70; average press., 50...	50
	5654.880
Travel of piston in feet per min.	300
	33,000)1696464.000
	51. horse power.

It has been found in practice that the maximum pressure in the cylinders of steam-engines and locomotives never exceeds $\frac{2}{3}$ the boiler pressure.



BALDWIN ANTHRACITE COAL-BURNING LOCOMOTIVE.

("Mogul" pattern.)

The annexed cut represents one of a class of Freight Locomotives built by the Baldwin Locomotive Works of Philadelphia for the *Russian* Government, to run on the *Voronge-Rostof* Railroad. Cylinder, 19 inches; stroke, 24 in.; diameter of drivers, 54 in.; revolutions per minute, 124; speed, 20 miles per hour; area of piston, 283.5 square inches; boiler pressure, 130 lbs.; maximum pressure in cylinder, 80 lbs.

$$\frac{283.5 \times 80 \times 4 \times 124 \times 2}{33,000} = 681.6 \text{ horse power.}$$

THE POWER OF THE LOCOMOTIVE.

In estimating the power of a locomotive, the term horse-power is not generally used, as the difference between a stationary steam-engine and a locomotive is such that while the stationary engine raises its load, or overcomes any directly opposing resistance, with an effect due to its capacity of cylinder, the load of a locomotive is drawn, and its resistance must be adapted to the simple adhesion of the engine, which is the measure of friction between the tires of the driving-wheels and the surface of the rails.

The power of the locomotive is measured in the moving force at the tread of the tires, and is called the traction force, and is equivalent to the load the locomotive could raise out of a pit by means of a rope passing over a pulley and attached to the circumference of the tire of one of the driving-wheels.

The adhesive power of a locomotive is the power of the engine derived from the weight on its driving-wheels, and their friction or adhesion on the rails. But the adhesion varies with the weight on the drivers and the state of the rails.

The tractive force of a locomotive is the power of the engine, derived from the pressure of steam on the piston, applied to the crank and radius of the wheels.

Rule for finding the Horse-power of a Locomotive.

Multiply the area of the piston by the pressure per square inch, which should be taken as $\frac{2}{3}$ the boiler pressure; multiply this product by the number of revolutions per minute; multiply this by twice the length of stroke in feet or inches;* multiply this product by 2, and divide by 33,000; the result will be the power of the locomotive.

EXAMPLE.

Cylinder, 19 inches.
Stroke, 24 "
Diameter of drivers, 54 inches.
Running speed, 20 miles per hour.
Area of piston, 283.5 square inches.
Boiler pressure, 130 pounds per square inch.
Maximum pressure in cylinders, 80 pounds.

$$\frac{283.5 \times 80 \times 4 \times 124 \times 2}{33{,}000} = 681.6 \text{ horse-power.}$$

RULES FOR CALCULATING THE TRACTIVE POWER OF LOCOMOTIVES.

Rule I. — Multiply the diameter of the cylinder in inches by itself; multiply the product by the

* If in inches they must be divided by 12.

mean pressure of steam in the cylinder in pounds per square inch; multiply this product by length of stroke in inches; divide the product by the diameter of the wheels in inches. Result equals the tractive force at the rails.

Rule 2. — *To calculate the load which can be hauled by an engine on a level at a given speed.* — Divide the tractive force, as per Rule 1, by the resistance in pounds per ton due to friction, imperfection of road, and winds. The quotient is the total load in tons, comprising the engine, tender, and train.

Rule 3. — *To calculate total resistance of engine, tender, and train at a given speed, due to friction, etc.* — Square the speed in miles per hour, divide it by 171, and add 8 to the quotient. The result is the total resistance at the rails in pounds per ton weight.

Rule 4. — *To find the load a locomotive can haul at a given speed on a given incline.* — Divide the tractive power of the engine in pounds by the resistance due to gravity on a given incline, added to resistance due to assumed velocity of train in pounds per ton; the quotient, less the weight of the engine and tender, equals the load in tons the engine can haul on a given incline.

Example, Rule I. — What is the tractive force of a locomotive 16 inch cylinder, 24 inch stroke, 4 feet drivers, mean pressure 80 pounds per square inch?

Cylinder, 16 inches......	16
	16
	96
	16
	256
Pressure in pounds, 80..	80
	20480
Stroke, 24 inches.........	24
	81920
	40960
Drivers 4 ft. or 48 in.....48)491520	
	10240 lbs. tractive force.

2000)10240 lbs. tractive force.
$5\frac{3}{25}$ tons.

Example, Rule 2. — What load can a locomotive, 16 inch cylinder, 24 inch stroke, 4 feet drivers, mean pressure 80 pounds, haul on a level at 30 miles per hour?

Tractive force, obtained as in Rule 1, is 10240 lbs.
Velocity per hour, 30 miles.

	30	13.26)10240
	30	$772\frac{1}{4}$ load in tons
	171)900	
Resistance in	5.26	
lbs. per ton,.........	8	
	13.26	

Example, Rule 4. — What load can a locomotive, 16 inch cylinder, 24 inch stroke, 4 feet drivers, mean pressure 80 pounds, haul on a grade of 132 feet to the mile at 30 miles per hour?

Tractive force, obtained as in Rule 1.....	10240 lbs
Resistance, in lbs. per ton, due to gravity (see Table of Gradients)............	56
Resistance, in lbs. per ton, due to friction, winds, etc..........	13.26
Total resistance in lbs. per ton............	69.26
Tractive force divided by total resistance equals load, in tons, engine can haul, less engine and tender...	69.26)10240.00 147.83
Weight of engine and tender in tons.....	55.65
Load in tons..................................	92.18

TABLE OF GRADIENTS.

RISE IN FEET PER MILE AND RESISTANCE DUE TO GRAVITY ALONE.

	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Rate of Gradient.......	20	25	30	35	40	45	50
Rise in feet per mile.	264	211	176	151	132	117	105
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Resistance in pounds per ton of train......	112	$89\frac{1}{2}$	$74\frac{1}{2}$	64	56	50	45

Resistance, due to gravity on any incline, in pounds per ton, of train, equals 2240 divided by rate of gradient.

EXAMPLE.

Gradient or rise of 1 foot in 20 feet.... ..2240 gross ton
20)2240
Resistance in lbs. per ton........... 112

The power of an engine may be roughly computed by calling it equal to $\frac{1}{6}$ of the weight on the driving-wheels, when the rails are wet or perfectly dry. Dampness or grease on the rails lessens the adhesive power of locomotives, as it is well known that the adhesion of engines is less in the neighborhood of depots and stations than it is out on the road. This arises from the quantity of oil that finds its way from the locomotives to the rails at oiling stations.

Adhesive Power of Locomotives per ton of Load on the Driving-wheels.

When rails are dry	600 lbs. per ton.
" " " wet	550 " " "
" " " damp	450 " " "
Foggy weather	300 " " "
Ice or snowy weather	200 " " "

Rule for finding the Power of a Locomotive.

Cylinder	18 inches.
Stroke	22 "
Running speed	20 miles per hour.
Steam pressure in boiler	125 lbs. per square inch.
Maximum pressure in cylinder	60 lbs. per square inch.
Revolutions	125 per minute, 20 miles per hour.
Area of piston	254.4 square inches.

$$\frac{254.4 \times 60 \times 44 \times 125 \times 2}{33{,}000 \times 12} = 424 \text{ horse power.}$$

PROPORTIONS OF LOCOMOTIVES ACCORDING TO BEST MODERN PRACTICE.

Diameter of cylinders	9 inches.
Length of stroke	16 "
Diameter of drivers	36 "
Wheel-base	6ft. 6 "
Capacity of tank	250 gallons.

Weight of Engine in Working Order.

25,000 pounds.

LOAD,

In addition to Weight of Engine.

On a level	565 gross tons.
" 20 feet grade per mile	265 "
" 40 " " "	170 "
" 60 " " "	125 "
" 80 " " "	100 "
" 100 " " "	80 "

Diameters of cylinders	10 inches.
Length of stroke	20 "
Diameter of drivers	54 "

Four-wheeled Truck with centre-bearing Bolster.

Diameter of wheels	24 inches.
Wheel-base	16ft. 3¾ "
Capacity of tank	900 gallons.

Weight of Engine in Working Order.

On drivers	23,000 pounds.
" trucks	15,000 "
Total weight of engine	38,000 "

LOAD,

In addition to Engine and Tender.

On a level	550	gross tons
" 20 feet grade per mile	250	"
" 40 " " "	160	"
" 60 " " "	115	"
" 80 " " "	85	"
" 100 " " "	65	"

Diameter of cylinders	11 inches.
Length of stroke	16 "
Diameter of drivers	36 "

Two-wheeled Truck with Swing Bolster and Radius bar.

Diameter of wheels	24 inches.
Wheel-base	11ft. 3 inches.
Rigid wheel-base	4 " 8 "
Capacity of tank	400 gallons.

Weight of Engine in Working Order.

On drivers	35,000 pounds.
" truck	5,000 "
Total weight of engine	40,000

LOAD,

In addition to Weight of Engine.

On a level	785	gross tons
" 20 feet grade per mile	370	"
" 40 " " "	240	"
" 60 " " "	175	"
" 80 " " "	135	"
" 100 " " "	110	"

Diameter of cylinders	12 inches.
Length of stroke	22 "
Diameter of drivers	54 to 60 "

Four-wheeled Truck with centre-bearing Bolster.

Diameter of wheels	24 to 26 inches.
Wheel-base	18 ft. 1 "

Tender on two four-wheeled Trucks.

Capacity of tank	1200 gallons.

Weight of Engine in Working Order.

On drivers	28,000 pounds.
" truck	16,000 "
Total weight of engine	44,000 "

LOAD,

In addition to Engine and Tender.

On a level	665	gross tons.
" 20 feet grade per mile	305	"
" 40 " " "	190	"
" 60 " " "	135	"
" 80 " " "	100	"
" 100 " " "	75	"

Diameter of cylinders	13 inches.
Length of stroke	22 to 24 "
Diameter of drivers	56 to 66 "

Four-wheeled centre-bearing Truck, with Swing Bolster.

Diameter of wheels	24 to 30 inches.
Wheel-base	20 ft. 1¼ "
Rigid wheel-base (distance between driving-wheel centres)	6 " 6 "

Tender on two four-wheeled Trucks.

Capacity of tank . . . . . . 1,400 gallons.

Weight of Engine in Working Order.

On drivers	30,000 pounds.
On truck	20,000 "
Total weight of engine	50,000 "

LOAD,

In addition to Engine and Tender.

On a level	710 gross tons.
" 20 feet grade per mile . . .	325 "
" 40 " " " " . . .	200 "
" 60 " " " " . . .	140 "
" 80 " " " " . . .	105 "
" 100 " " " " . . .	80 "

Diameter of cylinders	14 inches
Length of stroke	22 to 24 "
Diameter of drivers	56 to 66 "

Four-wheeled centre-bearing Truck, with Swing Bolster.

Diameter of wheels	24 to 30 inches.
Wheel-base	20 ft. 7¾ "
Rigid wheel-base (distance between driving-wheel centres)	7 "

Tender on two four-wheeled Trucks.

Capacity of tank . . . . . . 1,600 gallons.

Weight of Engine in Working Order.

On drivers	35,000 pounds.
On truck	20,000 "
Total weight of engine	55,000 "

LOAD,

In addition to Engine and Tender.

On a level	835 gross tons.
" 20 feet grade per mile . . .	380 "
" 40 " " " " . . .	240 "
" 60 " " " " . . .	170 "
" 80 " " " " . . .	124 "
" 100 " " " " . . .	100 "

Diameter of cylinders	15 inches.
Length of stroke	22 to 24 "
Diameter of drivers	56 to 66 "

Four-wheeled centre-bearing Truck, with Swing Bolster.

Diameter of wheels	24 to 30 inches.
Wheel-base	21 ft. 3 "
Rigid wheel-base (distance between driving-wheel centres)	7 " 8 "

Tender on two four-wheeled Trucks.

Capacity of tank . . . . . . 1,800 gallons.

Weight of Engine in Working Order.

On drivers	39,000 pounds.
On truck	21,000 "
Total weight of engine	60,000 "

LOAD,

In addition to Engine and Tender.

On a level	930 gross tons.
" 20 feet grade per mile . . .	430 "
" 40 " " " " . . .	270 "
" 60 " " " " . . .	190 "
" 80 " " " " . . .	140 "
" 100 " " " " . . .	110 "

Diameter of cylinders	16 inches
Length of stroke	22 to 24 "

Driving Wheels.

Rear and front pairs, with flanged tires .	5½ in. wide.
Main pair, with plain tires	6 "
Diameter of drivers	48 to 54 "

Four-wheeled centre-bearing Truck, with Swing Bolster.

Diameter of wheels	24 to 26 inches
Wheel-base	23 feet.
Rigid wheel-base (distance between centres of rear and front drivers) . .	12 feet 1 inch

Tender on two four-wheeled Trucks.

Capacity of tank	1,600 gallons.

Weight of Engine in Working Order.

On drivers	51,000 pounds.
On truck	16,000 "
Total weight of engine	67,000 "

LOAD,

In addition to Engine and Tender.

On a level	1,230 gross tons.
" 20 feet grade, per mile	570 "
" 40 " " " " . . .	360 "
" 60 " " " " . . .	260 "
" 80 " " " " . . .	195 "
" 100 " " " " . . .	155 "

Diameter of cylinders	17 inches.
Length of stroke	22 to 24 "
Diameter of drivers	56 to 66 "

Four-wheeled centre-bearing Truck, with Swing Bolster.

Diameter of wheels	24 to 30 inches.
Wheel-base	22 ft. 6½ "
Rigid wheel-base (distance between driving-wheel centres)	8 feet.

Tender on two four-wheeled Trucks.

Capacity of tank	2,000 gallons.

Weight of Engine in Working Order.

On drivers	45,000 pounds.
On truck	25,000 "
Total weight of engine	70,000 "

LOAD,

In addition to Engine and Tender.

On a level	1,075 gross tons.
" 20 feet grade per mile . . .	495 "
" 40 " " " " . . .	310 "
" 60 " " " " . . .	220 "
" 80 " " " " . . .	165 "
" 100 " " " " . . .	130 "

PROPORTIONS OF DIFFERENT PARTS OF LOCOMOTIVES, ACCORDING TO BEST MODERN PRACTICE.

In locomotive engines, the diameter of the cylinder varies less than in either stationary or marine engines. The range, with few exceptions, is between 10 and 20 inches.

Diameter of Cylinder.	Diameter of Main Steam Pipe	Diameter of Cylinder.	Diameter of Main Steam Pipe	Diameter of Cylinder.	Diameter of Main Steam Pipe.
8 in.	4½ in.	12 in.	5 in.	16 in.	6 in.
9 "	4½ "	13 "	5 "	17 "	6 "
10 "	4½ "	14 "	5 "	18 "	6 "
11 "	4½ "	15 "	6 "	20 "	6 "

Diameter of Cylinder.	Diameter of Piston Rod.	Valve Stems.	Diameter of Cylinder.	Diameter of Piston Rod.	Valve Stems.
8 in.	1½ in.	¾ in.	15 in.	2½ in.	1½ in.
9 "	1½ "	⅞ "	16 "	2½ C. eng.	1½ "
10 "	1¾ "	1 "	16 "	2¾ D. eng.	
11 "	2 "	1⅛ "	17 "	2¾ in.	1¾ "
12 "	2 "	1⅛ "	18 "	3 "	1⅞ "
13 "	2¼ "	1¼ "	19 "	3¼ "	
14 "	2¼ "	1⅜ "	20 "	3¼ "	2 "

Diameter of Cylinder.	Diameter of Pump Plunger.	Diameter of Cylinder.	Diameter of Pump Plunger.	Diameter of Cylinder.	Diameter of Pump Plunger.
7 in.	1 in.	12 in.	1½ in.	16 in.	1¾ in.
8 "	1 "	12 "	1¾ "	16 "	2 "
9 "	1⅛ "	13 "	1⅝ "	17 "	1⅞ "
10 "	1¼ "	14 "	1⅝ "	17 "	2 "
11 "	1⅜ "	14 "	1⅞ "	18 "	2⅛ "
11 "	1⅝ "	15 "	1¾ "	20 "	2¼ "

Diameter of Cylinder.	Diameter of Crank Pins.	Diameter of Cylinder.	Diameter of Crank Pins.	Diameter of Cylinder.	Diameter of Crank Pins.
7 in.	2½ in.	12 in.	3 in.	17 in.	3½ in.
8 "	2¾ "	13 "	3¼ "	17 "	3¾ "
9 "	2¾ "	14 "	3¼ "	18 "	4 "
10 "	3 "	15 "	3½ "	19 "	4½ "
11 "	3 "	16 "	3½ "	20 "	4¾ "

Diameter of Cylinder.	Length of M'n Crank in Bearing.	Diameter of Cylinder.	Length of M'n Crank in Bearing.	Diameter of Cylinder.	Length of MainCrank in Bearing
8 in.	2½ in.	12 in.	3¼ in.	16 in.	3¾ in.
9 "	2¾ "	13 "	3¼ "	17 "	4 "
10 "	3 "	14 "	3½ "	18 "	4½ "
11 "	3 "	15 "	3½ "	20 "	4¾–5 "

Diameter of Cylinder.	Diameter of Reverse Shaft Bearings.	Diameter of Cylinder.	Diameter of Reverse Shaft Bearings.	Diameter of Cylinder.	Diameter of Reverse Shaft Bearings.
8 in.	1½ in.	12 in.	2 in.	16 in.	2 in.
9 "	1½ "	13 "	2 "	17 "	2 "
10 "	1¾ "	14 "	2 "	18 "	2 "
11 "	1¾ "	15 "	2 "	20 "	2 "

Diameter of Cylinder.	Depth of Main Rods.		Thick.	Diameter of Cylinder.	Depth of Main Rods.		Thick.
	Front End.	Back End.			Front End.	Back End.	
8 in.	2¼	2	1½ in.	15 in.	3¼	2⅞	1⅞ in.
9 "	2½	2	1⅝ "	16 "	3½	3	2⅞ "
10 "	2¾	2½	1¾ "	17 "	3½	3	1⅞ "
11 "	2¾	2½	1¾ "	18 "	3¾	3	2 "
12 "	2⅞	2¾	1⅞ "	19 "	4	3¼	2 "
14 "	3	2¾	1⅞ "	20 "	4¼	3½	2⅛ "

Diameter of Cylinder.	Diameter of Journals Driving Axles.	Length of Journals.	Diameter of Cylinder.	Diameter of Journals Driving Axles.	Length of Journals.
7 in.	4 in.	4¾ in.	14 in.	6 in.	6¼ in.
8 "	4¼ "	5 "	15 "	6½ "	6¾ "
9 "	4¼ "	5¼ "	16 "	7 "	8 "
10 "	4¼ "	5½ "	16 "	6 "	7 "
11 "	4½ "	5½ "	17 "	6 "	7 "
12 "	5¼ "	6¼ "	18 "	6½ "	7½ "
13 "	5½ "	6½ "	20 "	6½ "	7½ "

Diameter of Cylinder.	Steam-port.	Exhaust-port.	Bridges.
8	7½×⅝	7½×1¼	⅝
9	7½×¾	7½×1½	¾
10	7½×¾	7½×1½	¾
11	10 ×1	10 ×2	⅞
12	10 ×1	10 ×2	⅞
13	12 ×1¼	12 ×2½	1
14	13 ×1¼	13 ×2½	1
15	14 ×1¼	14 ×2½	1
16	15 ×1¼	15 ×2½	1
17	16 ×1¼	16 ×2½	1
18	17 ×1¼	17 ×2½	1
20	18 ×1¼	18 ×2½	1

TABLE

SHOWING THE TRAVEL OF VALVE AND THE AMOUNT OF LAP AND LEAD FOR DIFFERENT POINTS OF CUT-OFF, AND THE DISTANCE THE STEAM FOLLOWS THE PISTON ON THE FORWARD MOTION.

EXAMPLE.

Size of Cylinder, 16×24 inches; Travel of Valve, 5½ inches; Lap, ⅞ inch outside; Line and Line inside; Steam Ports, 15×1¼ inches; Exhaust, 2½ inches.

Cut-off.	Lead.	Travel of Valve.	Distance Steam follows Piston, Forward Motion.
6 in.	$\frac{5}{32}$	$2\frac{3}{8}$	$15\frac{3}{4}$
9 "	$\frac{5}{32}$	$2\frac{9}{16}$	$17\frac{15}{16}$
12 "	$\frac{1}{4}$	$2\frac{3}{4}$	$19\frac{1}{16}$
15 "	$\frac{7}{32}$	$3\frac{1}{8}$	$20\frac{1}{2}$
18 "	$\frac{7}{36}$	$3\frac{13}{16}$	$21\frac{15}{16}$
24 "	$\frac{1}{16}$	$5\frac{1}{16}$	$23\frac{1}{8}$

Average Proportions of Different Parts of Locomotives.

Area of steam-ports equal to $\frac{1}{12}$ area of cylinder.
Area of exhaust-port equal to $\frac{1}{6}$ area of cylinder.
Area of main steam-pipe from $\frac{1}{4}$ to $\frac{1}{8}$ area of cylinder.
Diameter of piston-rods $\frac{1}{6}$ the diameter of cylinder.
Diameter of crank-pin $\frac{1}{4}$ the diameter of cylinder.
Diameter of valve stems $\frac{1}{10}$ the diameter of cylinder.
Diameter of pump-plunger $\frac{1}{5}$ the diameter of cylinder.

RULES.

Rule.— *To find the Size of the Steam-ports for Locomotive Engines.*—Multiply the square of the diameter of the cylinder by .078. The product is the proper size of the steam-ports in square inches.

Rule.—*To find the Area of Exhaust-ports.*—Multiply the square of the diameter of the cylinder in inches by .178. The product is the area of the eduction ports in square inches.

Rule.—*To find the Diameter of the Steam-pipe of Locomotive Engines.*—Multiply the square of the diameter of the cylinder in inches by .03. The product is the diameter of the steam-pipe in inches.

Rule.—*To find the Diameter of the Piston-rod for Locomotive Engines.*—Divide the diameter of the cylinder in inches by 6. The quotient is the diameter of the piston-rod in inches.

Rule.—*To find the Diameter of the Crank-pin for Locomotive Engines.*—Multiply the diameter of the cylinder in inches by .234. The product is the diameter of the crank-pin in inches.

Rule.—*To find the Diameter of the Feed-pump Ram.*—Multiply the square of the diameter of the cylinder in inches by .0083. The product is the diameter of the ram in inches.

LOCOMOTIVE BUILDING.

Though locomotive building has long ceased to be considered an art, yet it requires the utmost attention in respect to general design, construction, and the selection of materials; and for this reason all the principal parts are made according to accurate drafts, templets, and gauges in their respective departments before being taken to the erecting shop to be united in the construction of the engine.

CONSTRUCTION OF LOCOMOTIVES.

The boiler is first placed horizontal on the construction track, and levelled by the dome top.

The cylinders are next placed under the front end of the boiler, with the smoke-box resting in the saddles of the cylinders. The cylinders are then levelled by their valve seats.

Lines are now accurately drawn through the centre of the cylinders to the back end of the boiler, and the frames set up temporarily according to the lines drawn through the cylinders.

The frame gauges are next placed on the frames, for the purpose of holding them in their right position and proper distance apart.

Lines are again drawn through the centre of the cylinders to the back end of the frame, for the purpose of determining if the frames are parallel at both ends, and with the cylinders.

Straight-edges are now laid across the top of the frames, to determine whether the frames are level or not, and also if the distance from the top of the frame to the centres of the cylinders corresponds exactly.

The distance between the frames and the shell of the boiler is next measured, to ascertain the thickness of the liners.

The furnace-pads are then placed in position and marked, counter-sunk, or planed to correspond with the ends of the stay-bolts on the outside of the furnace sheet, and also to stand parallel with the outside of the frames.

The cylinders are next bolted to the smoke-arch, and the frames to the cylinders.

The foot-plate is now placed on the frame, at the back end of the boiler; also, the back furnace braces and cross-ties fitted, drilled, and bolted to their respective places.

The waste-sheet is then attached to the waste of the boiler, and the guide-braces and guide-bearers made fast to the boiler and the frames.

The guides, cross-heads and back-heads of cylinders are next put on, and the pistons inserted in the cylinders and keyed to the cross-heads.

The smoke-box braces are then fitted and drilled, and the centre casting bolted to the smoke-box.

The flues, steam-pipe, throttle-pipe, throttle-valve, and arch-pipes are next placed in the boiler, and the safety-valves and whistle-stand attached to the steam dome.

The boiler is then put under steam for the purpose of determining if it leaks or needs caulking. Then the boiler, cylinders, and steam domes are lagged and jacketed.

The frame is now jacked up, the driving-wheels placed in the pedestals, the boxes secured by means of keys and wedges, and the pedestal caps put on.

The rocker boxes are next bolted to the frame, and the rocker shafts placed in their proper positions. The rockers and rocker boxes need to be adjusted with a great deal of accuracy, as any slight divergence of the rockers from correct lines would derange the whole valve gear.

The reverse shaft is then fastened on the frame by means of clamps, and its proper place determined by accurate measurements from its centres to the centres of the rockers.

The valves are then placed on their seats in the steam-chest, and the valve-yokes and valve-rods attached to the rocker-arms.

The eccentric straps and eccentric rods are next attached to the links, and the link-block connected with the rocker. Then everything is ready to set the valves.

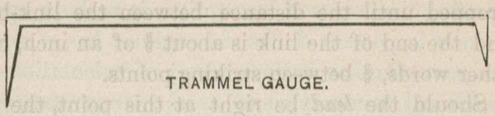
SETTING THE VALVES OF LOCOMOTIVES.

Setting the valves of locomotives is perhaps one of the most important duties the engineer has to undertake, involving, as it does, nicety of calculation and mechanical accuracy; and as the circumstances of construction, valve gear, pressure, and work to be done varies, it will at once be apparent that no one uniform rule for valve setting can be laid down.

Everything being ready to set the valves of the locomotive, the main rods are put on, and the driving-wheels blocked up until the centre of the driving-boxes are parallel with centre of the cylinders; the wedges in the driving-boxes are then set up to prevent lost motion.

A circle is next described on the hub of the driving-wheel equal in diameter to the width of the straps on the main rods; a straight-edge is now placed on the strap, and the wheels moved forward until the position of the straight-edge on the top and bottom of the strap is parallel with the sides of the circle on the hub of the wheel.

A centre-punch mark is then made on the frame, in which one point of a trammel-gauge is inserted, and with the other point a mark is described on the face of the tire of the driving-wheel. Another centre-punch mark is made on the guide even with the end of the cross-head at its farthest travel. These marks represent the position of the crank and cross-head at full stroke, or when the crank is at the dead centre on the forward motion.



TRAMMEL GAUGE.

Now, if the engine is 24-inch stroke, the wheel is moved forward until the cross-head travels 12 inches from the centre-punch mark on the end of the guide. The point of the trammel-gauge is now inserted in the centre-punch mark on the frame, and another mark is described on the face of the tire of the driving-wheel; these points represent the position of the crank and cross-head at half-stroke.

The wheel is again turned forward until the dead centre is reached, or until the lines on the top and bottom of the strap correspond with the circle on the hub of the wheel; here another mark is made on the guide at the end of the cross-head. At this point also another centre-punch mark is made on the frame, and with the tram a mark is described on the face of the tire as before.

The wheel is then turned forward until the cross-head travels 12 inches from the last mark made on the guide. Then the point of the tram is inserted in the centre-punch mark on the frame, and another mark described on the face of the tire of the driving-wheel. Now, these four marks will represent the four centres of the wheel on that side.

The wheel is next turned until the dead centre is reached on the forward motion, and the reverse lever dropped until the distance between the link-block and the end of the link is about $\frac{3}{8}$ of an inch, or, in other words, $\frac{3}{8}$ between striking points.

Should the *lead* be right at this point, the position of the reverse latch is marked on the quadrant; but if more or less than the required amount, the adjustment is made by moving the eccentric and lengthening or shortening the eccentric rods by means of slotted holes at the point where the rods are connected with the straps. But it must be remembered that the *lead* is always adjusted by moving the eccentrics, and the dividing is effected by shortening or lengthening the rods.

The wheel is moved forward again to the other centre, for the purpose of determining if the *lead* is right at that end of the stroke; and if it should be found to be more or less, the adjustment is made as before by moving the eccentric, and the lengthening or shortening is done by the rods in the slotted holes.

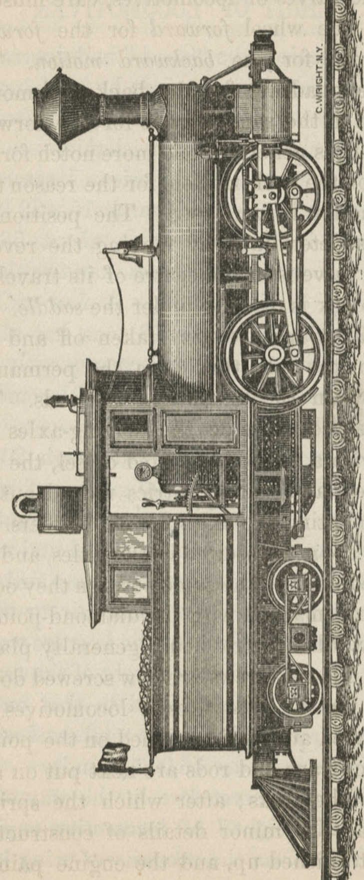
The wheel is again turned forward until the cross-head moves 12 inches, and the valve is at its farthest travel. The position of the reverse latch is marked on the quadrant at this point, which gives the full opening of the port when the link is in full gear. The intermediate points of cut-off are then marked on the quadrant, which, for an engine 24-inch stroke, are generally 6, 9, 12, 15, 18.

In setting the valves of locomotives, care must be taken to turn the wheel *forward* for the *forward motion,* and *back* for the *backward motion.* The notches on the quadrant for the backward motion are determined in the same way as for the forward motion, but there is generally one more notch for the forward than for the back motion, for the reason that the forward motion is more used. The position of the *out-notch* is determined by moving the reverse lever until the valve is in the centre of its travel, or until the link-block is directly under the *saddle.*

The eccentric straps are next taken off and the holes drilled for the bolts that form the permanent connection between the straps and the rods. The positions of the eccentrics on the driving-axles are next marked with a diamond-pointed chisel, the set-screws slackened, and the eccentrics moved out for the purpose of slotting the axles for the feathers.

The feathers are next inserted in the axles, and the eccentrics forced back to the same position they occupied before being marked with the diamond-pointed chisel; the forward eccentric being generally placed on the inside. The set-screws are now screwed down. The set-screws for the eccentrics of locomotives are generally concaved and case-hardened on the points.

The eccentric straps and rods are next put on and connected with the links; after which the springs are mounted, all the minor details of construction and adjustment finished up, and the engine painted and made ready for the road.



FORNEY'S IMPROVED TANK LOCOMOTIVE.

The American locomotive, the last great crowning invention of the human intellect, has no peer for beauty of design, or in the performance of its work.

DEAD WEIGHT OF LOCOMOTIVES.

The idea of lessening the "dead" and increasing the "paying" weight of locomotives, by utilizing the weight of fuel and water, and the tanks for the same, early suggested itself to railroad mechanics.

An ordinary eight-wheeled American locomotive, with four 5-feet driving-wheels, and 15×22 inch cylinders, weighs, in working order, about 58,000 pounds, of which about 36,000, or less than two-thirds, is carried on the driving-wheels. A four-wheeled switching engine, which weighs 18 tons, has all its weight on the driving-wheels, and consequently will draw as many cars as an eight-wheeled locomotive weighing 29 tons.

The tender of such an engine will weigh 20,000 pounds empty, and will carry 1,800 gallons of water and three tons of coal, making a total weight of 41,000 pounds. And as the supply of fuel and water varies very much, the tank being sometimes full but very seldom empty, it would be about fair to count two-thirds of the water and coal as the average weight carried. Therefore the average weight of the tender will be 34,000 pounds, which, added to that on the truck of the engine, would make the total *dead weight* of the locomotive and tender 56,000 pounds.

The great difficulty heretofore in the way of reducing the "dead weight" of locomotive engines, would seem to arise from the necessity of using large

boilers, the value or efficiency of the engine being dependent upon its boiler capacity; and as large boilers must of necessity be accompanied by weight in proportion to their size, the theory of reduction of dead weight, in engines, seems to be reduced to two propositions, viz., lighter boilers or lighter parts.

But as the nominal adhesion of the standard eight-wheel American engine is often insufficient as at present constructed, hence it follows that if the weight be materially reduced, a large proportion of the remaining weight must be placed upon the driving-wheels.

Various new systems and theories have been urged at different times with a view of lessening the "dead" and increasing the "paying" weight on railroads. Tank engines seem to offer the most practical solution of the problem involved in the reduction of dead weight, as the tender can be, to a certain extent, dispensed with, and the weight of the water and fuel utilized on the drivers.

It is true that water and fuel stations would have to be arranged nearer each other than is usual with the present system of engine and tender. But it is claimed that the facility with which tank engines run backward or forward, thus dispensing with turn-tables, and saving the time ordinarily consumed in turning, would more than counterbalance the additional expense incurred in the increase of the fuel and water stations. It is a fact not sufficiently borne in mind that there is a good deal of unnecessary expense involved in hauling large weights of fuel and water over long distances on tenders.

The *locomotive* represented on page 125 was especially designed to overcome the evil above mentioned. By this plan not only is all the weight of the boiler and machinery carried by the driving-wheels, but by extending the frame beyond the fire-box far enough to receive the tank, and placing a truck underneath to carry the weight of water and fuel, a long wheel-base is secured, which adjusts itself to the curvature of the track, while at the same time the whole weight of the engine and boiler is carried on the driving-wheels. By this means the galloping motion common in tank engines is obviated, and the steadiness of an ordinary eight-wheel locomotive is attained.

The *tank engine* described in the above paragraph has been designed to run with its truck ahead; and as one of the essential features of the plan is to carry the boiler and machinery, whose weight is permanent, on the driving-wheels, and the water and fuel, which are variable, on the truck, therefore, running the locomotive in this way reverses the positions of the different parts, and brings the boiler, smoke-stack, etc., behind, which is claimed to be an advantage, as when a locomotive runs with the smoke-box ahead, the smoke in the tubes moves in the same direction as the locomotive, consequently the draft created by the

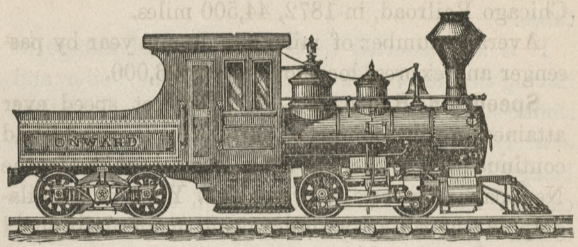
movement of the latter retards the draft in the tubes.

It is also asserted that there is an advantage in having the water-tank in front, and the boiler and smoke-stack behind. The view of the track is thus entirely unobstructed, and there is no liability of its being obstructed by smoke or escape steam. The cabs of tank engines of this plan can be entirely closed up in cold weather, as it is not necessary to keep a communication to a separate tender open, as on ordinary engines.

TABLE

SHOWING THE NUMBER OF REVOLUTIONS PER MINUTE MADE BY DRIVERS OF LOCOMOTIVES OF DIFFERENT DIAMETERS AND AT DIFFERENT SPEEDS.

Driving wheel Diameter.	Speed in Miles per Hour.						Revolutions per Mile.
	20	25	30	35	40	50	
4 ft. 0 in.	140	175	210	.....	.....		420
4 " 3 "	132	165	198	.....	.....		395.5
4 " 6 "	124	156	186	.....	.....		373.6
4 " 9 "	118	148	177	207	.....	Revolutions per Minute.	354
5 " 0 "		140	168	196	.....		336
5 " 3 "		134	160	187	.....		320.2
5 " 6 "		128	153	179	204		305.9
5 " 9 "	Revolutions per Minute.	.....	146	170	195		292.3
6 " 0 "		.....	140	163	187		280.3
6 " 3 "		.....	135	157	179	224	269
6 " 6 "		.....	129	150	172	216	258.6
7 " 0 "		.....	120	140	160	200	240



NARROW-GAUGE FAIRLIE LOCOMOTIVE.

The above cut represents one of "Mason's Narrow-Gauge" Fairlie Locomotives. On this class of engines the tank is bolted to the boiler, and rests on two trucks with centre-pins, which enables it to pass around sharp curves with ease. The steam-pipes have ground joints, and turn in their socket when the engine is going around a curve.

Number of Locomotives in the United States.— Whole number of locomotives in use in the United States at the close of 1873 was 14,200.

Age of Locomotives. — Locomotives Nos. 1 and 2 built by Braithwaite & Co., London, England, 1838, or nine years after George Stephenson's "Rocket" was placed on the track, are still running on the Reading Railroad, at Port Richmond, Philadelphia.

Number of Miles Run by Locomotives. — Engine No. 49 on the Reading Railroad, from August 1st, 1857, to November 1st, 1873, 447,138 miles.

Number of Miles Run by Locomotives in One Year. — Engine 46 on the Pittsburg, Fort Wayne and Chicago Railroad, in 1872, 44,500 miles.

Average number of miles run in one year by passenger and express locomotives was 26,000.

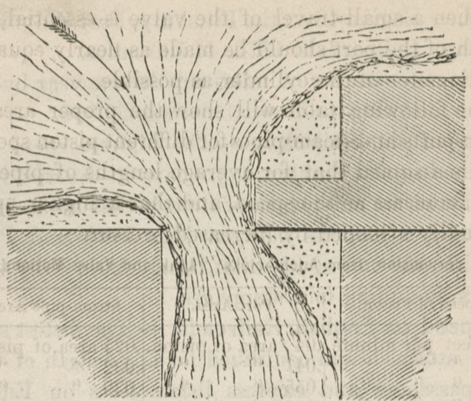
Speed on Railroads. — The highest speed ever attained in this country, or perhaps in the world, and continued for any length of time, is that made by the Newspaper Express between New York and Philadelphia, the run of 93 miles being made daily in 1¾ hours, including four stoppages.

Speed on English Railroads. — The fastest speed ever attained, and continued for any length of time, by passenger and express locomotives on English railroads, was 50 miles per hour; the average speed being about 35 miles per hour.

Average speed of freight locomotives in England, about 15 miles per hour.

Average speed of freight locomotives in the United States, about 12 miles per hour.

Heavy Locomotives. — The largest locomotive in the world is the "Pennsylvania," on the Reading Railroad. Diameter of cylinders, 20 inches; stroke, 26 inches; number of driving-wheels, 12; diameter of drivers, 4 feet; weight of engine alone, 60 tons. The heaviest locomotives in Europe are the four-cylinder freight engines on the Northern Railway of France. Cylinders, 18 inches; stroke, 18 inches; 12 coupled wheels, 42 inches diameter; weight of locomotive, 66 tons.



STEAM-PORTS.

The dimensions of the steam-ports rank next in importance to the cut-off in their controlling influence upon the proportions of the valve seat and face. They may justly be considered as a *base,* from which all the other dimensions are derived, in conformity with certain mechanical laws.

Their value depends greatly upon the manner in which the ports are employed, whether simply for admitting the steam to the cylinder, or for purposes both of admission and escape.

In case of admission, if the port is properly designed, it is evident that the pressure will be sustained at substantially a constant quantity by the flow of steam from the boiler. But with the exhaust the case is different, as the steam is forced into the atmosphere with a constantly diminishing pressure and less velocity.

When a small travel of the valve is essential, the length of the port should be made as nearly equal to the diameter of the cylinder as possible.

The following table will show the proper area of steam-ports and steam-pipes for different piston speeds, as it is assumed that for average lengths of pipe the area increases as the speed, and that a higher speed is usually attended by increased pressure:

(By permission, from Auchincloss' "Link and Valve Motions.")

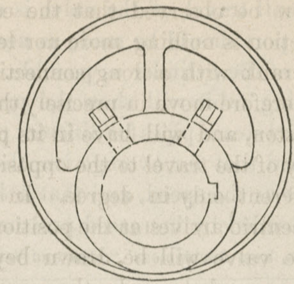
Speed of Piston.	Port Area.	Steam-pipe Area.
200 feet per minute.	.04 area of piston.	.025 area of piston.
250 " " "	.047 " "	.032 " "
300 " " "	.055 " "	.039 " "
350 " " "	.062 " "	.046 " "
400 " " "	.07 " "	.053 " "
450 " " "	.077 " "	.06 " "
500 " " "	.085 " "	.067 " "
550 " " "	.092 " "	.074 " "
600 " " "	.1 " "	.08 " "

BRIDGES.

The width of the bridges is usually made of equal thickness with the cylinder, in order to secure a perfect casting; but at times it becomes necessary to increase or decrease their width.

The only danger from a narrow bridge is an *over-travel* of the valve, by which the exhaust passage would be placed in direct communication with the "live steam" in the chest, and followed by continual waste of the power.

The width of bridges for different size cylinders of locomotives varies from ⅝ up to 1¼ inches.



ECCENTRICS.

The term eccentric is applied in general to all such curves as are composed of points situated at unequal distances from a central point or axis.

Upon close inspection it appears that this is only a mechanical subterfuge for a small crank.

This being so, a crank of the ordinary form may be, and frequently is, used instead of an eccentric — in point of fact, the latter is the real substitute, being a mechanical equivalent introduced, because the use of the *crank* is, for special reasons, inconvenient or impracticable.

And since the shaft to which the eccentric is fixed here makes a half revolution while the piston is making one stroke, it follows that whatever device may be used for converting the reciprocating motion of the piston into rotatory motion, the slide-valve may be actuated by an eccentric fixed on any shaft which makes a half revolution at each stroke of the piston.

It will now be observed that the eccentric and valve connection is nothing more nor less than that of a small crank with a long connecting rod; the valve will therefore move in precisely the same manner as the piston, and will have in its progress from one extremity of the travel to the opposite like irregularities, different only in degree. In other words, when the eccentric arrives at the positions for cut-off and lead, the valve will be drawn beyond its true position — measured towards the eccentric — by a distance dependent on the ratio between the throw of the eccentric and the length of its rod.

When the eccentric stands at right angles to the crank, the exhaust closes and release commences at the *extremities* of the stroke; consequently, if the eccentric be moved ahead 30°, not only will the cut-off take place 30° earlier, or at a crank-angle of 120° instead of 150°, but the release, as well as the exhaust, will take place 30° earlier, or at the 150° crank-angle.

For a cut-off, say of 140°, there would be required an angular advance of 20°, and a lap equivalent to the distance these degrees remove the eccentric centre from the line at right angles to the crank; for a cut-off of 160°, an advance of 10°, with a corresponding lap, and so on, the exhaust closure taking place respectively at the 160° and 170° crank-angles.

This closure of the exhaust confines the steam in the cylinder until the port is again opened for the return stroke; consequently the piston in its progress will meet with increasing resistance from the steam, which it thus compresses into a less and less volume.

Such opposition, when nicely proportioned, aids in overcoming the momentum stored up in the reciprocating parts of the engine, and tends to bring them to a uniform state of rest at the end of each stroke.

Since the closure of one port is simultaneous with the opening of the other, a release will take the place of the steam which was previously impelling the piston.

Within certain limits an early release is productive of a perfect action of the parts, for an early release enables a greater portion of the steam to escape before the return stroke commences; whereas, a release at the end of the stroke would be attended by a resistance of the piston's progress, from the simple fact that steam *cannot* èscape instantaneously through a small passage, but requires a certain definite portion of time, dependent on the area of the opening and the pressure.

The *advance* of the eccentric denotes the angle which the eccentric forms with its position at half-stroke, when the piston is at the commencement of its stroke, and is called *Angular Advance.*

ECCENTRIC RODS.

The variable character of the lead opening, in a shifting-link motion, depends upon the manner in

which its eccentric rods are attached, and its amount depends on the length of those rods.

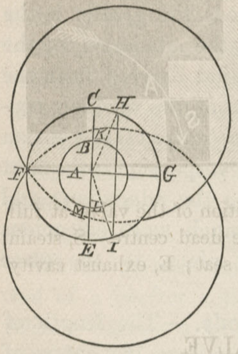
The shorter the eccentric rods the greater is the front admission, and the less is the admission for the back. The quality of the motion derived from the link is modified by the position of the working centres, and most especially of the centre of suspension and connection. The centre of suspension is the most influential of all in regulating the admission; and its transition horizontally is much more efficacious than a vertical change of place, to the same extent.

Length of the Eccentric Rods.—The length of the eccentric rod is the distance from the centre of the driving-axle to the centre of the rocker-pin, when the rocker stands plumb.

Formula by which to find the Positions of the Eccentric on the Shaft.

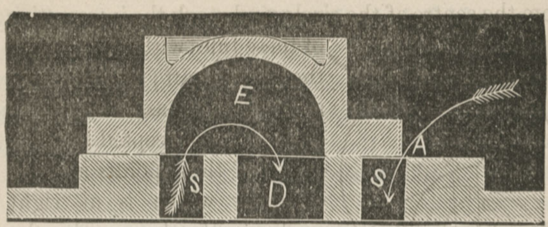
First. Draw upon a board two straight lines at right angles to one another, and from their point of intersection as a centre describe two circles, one representing the circle of the eccentric, the other the crank shaft; draw a straight line parallel to one of the diameters, and distant from it the amount of lap and lead; the points in which this parallel intersects the circle of the eccentric are the positions of the forward and backing eccentrics.

Second. Through these points draw straight lines from the centre of the circle, and mark the intersection of these lines with the circle of the crank-shaft; measure with a pair of compasses the chord of the arc intercepted between either of these points and the diameter which is at right angles with the crank, the diameters being first marked on the shaft itself; then by transferring with the compasses the distance found in the diagram, and marking the point, the eccentric may at any time be adjusted without difficulty.



Example. — Let F G and E C be the two straight lines at right angles to each other; the circle described with A B as a radius be the end view of the shaft; the circle described with A C as a radius be the circle described by the centre of the eccentrics; and H I the line parallel to E C, and distant from it the amount of the lap and lead.

Then if F G represents the direction of the crank when on the centre, H and I will be the positions of the centres of the eccentrics, according to the rule. If, then, the points K and L, in which the lines A H and A I intersect the circle representing the shaft. be transferred to the shaft, by laying off on its end the two diameters, and the chords B K and L M, the eccentrics can readily be set.



The above cut represents the position of the valve at full stroke, or when the crank is at the dead centre. S, steam ports; D, exhaust opening in valve seat; E, exhaust cavity in valve; A, *lead.*

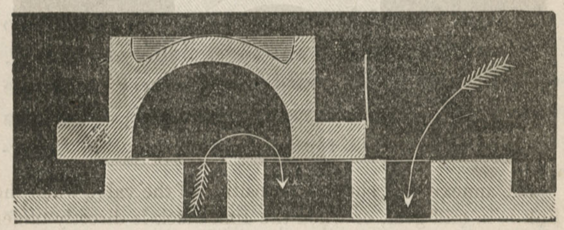
THE SLIDE-VALVE.

The slide-valve is that part of a steam-engine which causes the motion of the piston to be reciprocating. It is made to slide upon a smooth surface, called the valve seat, in which there are three openings — two for the admission of steam to the cylinder alternately, while the use of the third is to convey away the waste steam. The first two are, therefore, termed the steam-ports, and the remaining the eduction or exhaust port.

In examining the special application of the slide-valve to the steam-engine, it will be necessary to consider what the requirements of the engine are; for the valves, of whatever kind, being to that machine what the lungs are to the body, must necessarily be so actuated as to regulate the admission and escape of the steam, which is its breath, in accordance with the conditions imposed by the motion of the piston.

The valve may be said to be the vital principle of the engine. It controls the outlet to the coal and wood pile. It is, therefore, of the highest importance that it should work practically under all circumstances.

Now the admission of steam is one thing and its escape is another, and though both may be regulated by what is called one valve, because it is made in one piece, yet this is not by any means necessary. Four separate valves may be, and sometimes are, employed in stationary engines—a steam and an exhaust valve at each end of the cylinder; but the functions of all these are distinctly performed by the common three-ported slide-valve.



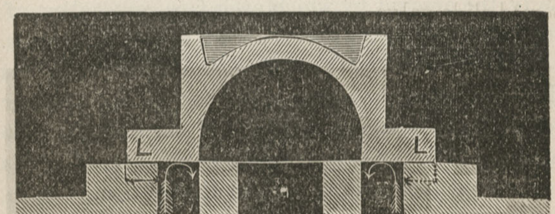
Position of the valve at half stroke.

It is evident that the admission cannot continue longer, in any case, than the stroke does, so that by

the time that is completed, the valve must have opened and closed the port. These conditions determine the modification of the movement which must be used, and the greatest breadth of the port for any assumed travel of valve.

When the motion of a slide-valve is produced by means of an eccentric, keyed to the crank-shaft and revolving with it, the relative positions of the piston and slide-valve depend upon the relative positions of the crank and eccentric.

The greatest opening of the port is half the travel of the valve; in this case the steam is admitted during the whole stroke of the piston, at the beginning of which the valve, which has no lap, is at the centre of its travel.



The annexed cut shows the position of the valve when the link is in mid-gear, or when the link-block is directly under the saddle, and the reverse latch in the *out notch*. L represents the lap.

If the eccentric be so placed that at the beginning of the stroke of the piston the valve is not at the centre of its travel, the opening of the port will be reduced, and it will be closed before the piston completes its stroke.

In this case, the opening of the port will be less than half the travel, by as much as the valve, at the beginning of the stroke of the piston, varies from its original central position. And when the valve is at half stroke it will overlap the port on the opening edge to the same extent.

The point in the stroke of the piston at which the port will be closed and the steam cut off, will depend upon the angular position of the eccentric at the beginning of the stroke.

When the valve is so formed that, at half stroke, the faces of the valve do not close the steam-ports internally, the amount by which each face comes short of the inner edge of the port is known as *inside clearance.*

From the nature of the valve motion, it follows that the distribution is controlled by the "outer and inner edges of the extreme ports and of the valve." The mere width of the exhaust-port or thickness of bars is immaterial to the timing of the distribution.

The extreme edges of the steam-ports and those of the valve regulate the admission and suppression; and the inner edges of the ports and the valve command the release and compression.

For every stroke of the piston, four distinct events occur — the admission, the suppression, the release, and the compression.

The *advance* of the *valve* denotes the amount by which the valve has travelled beyond its middle position, when the piston is at the end of the stroke, and is known as *linear advance.*

The slide-valve is said to be very imperfect and wasteful of fuel; but, on account of its simplicity, durability, and positive action, it has been able to compete with the best modern improvements, and it is at the present time the only valve in use on all the railroads in the world.

With all its defects it must be conceded that nothing has yet been introduced that has so well answered the purpose of controlling the induction and eduction of steam to the locomotive cylinder as the ordinary slide valve, nor does it at present seem probable that it ever will be superseded.

FRICTION ON THE SLIDE-VALVE.

The great aim of all engineers has been to remove the weight caused by the pressure of the steam from the back of the slide-valve; but it has been considered almost impossible to produce a frictionless slide-valve.

The percentage of the friction of the slide-valve, as compared with the cylinder's power, ranges between 10 and 20 per cent., according to the condition of the valve, variation in the position of the gear, etc.; for while the cylinder decreases in power as the crank approaches the end of the stroke, the friction of the valve and eccentrics increases.

Length of the Valve Rods.—The length of the valve rods is the distance from the centre of the rocker pins to the centre of the valves, when the valves are placed centrally over the ports and the rocker arm stands plumb.

LAP AND LEAD OF VALVE.

Lap, or lap of valve, is understood to be the distance the valve overlaps each steam opening when placed centrally over the port. The amount of lap is regulated by the point at which the steam is to be cut off, or the degree of expansion to be attained, as without *lap* there would be no expansion, because the suppression and release would occur at the same time.

Lap on the steam side is termed *outside lap.* Lap on the exhaust side is known as *inside lap.*

Lead of Valve.—*Lead* is understood to be the width of port opening given by any valve on the steam end when the crank is at either dead centres, and the angular distance of the crank from its zero at the instant this opening commences, is termed *lead angle.*

Lead on the steam side is denominated *outside lead,* or lead for the admission; on the exhaust side it is *inside lead,* or lead for the exhaust.

Lap and Lead of Valve.—Lap and lead procure an early and efficient release, because the lead of the exhaust, or the amount by which the valve is open to the exhaust, at the end of the stroke, is increased by as much as the addition of lap on the outside.

Lap, Lead, and Travel of Valve.—As *lap, lead,* and *travel* regulate the distribution of steam, an alteration of any one of these affects it in a definable manner. If they be equally varied in conjunction, the distribution remains the same.

BALANCED SLIDE-VALVE.

The mechanical difficulty of producing a practical balanced slide-valve, trustworthy under every kind of locomotive work, seems to have been successfully overcome. Balanced valves are now in use on nearly all the principal railroads in the country, and are said to meet all the demands of locomotive practice.

It is claimed that the saving in the wear and tear of valve motion with balanced valves, especially in the case of large engines, is very great, as they can be kept out of the repair shop much longer than engines with common slide-valves.

It is also asserted by railway mechanics that they are not liable to any sudden derangement, either on fast passenger trains or on freight trains; and the comfort of the drivers is greatly enhanced by having an engine that can be notched up or reversed as easily with the throttle open as shut.

Miles ran with balanced valves without facing, 75,000 to 150,000; miles run with common slide-valves without facing, 30,000 to 50,000.

TABLE

SHOWING THE AMOUNT OF LAP AND LEAD ON THE VALVES OF LOCOMOTIVES IN PRACTICE, ON 35 OF THE PRINCIPAL RAILROADS IN THIS COUNTRY.

Locomotives Running Express Passenger Trains.

25 use
- $\frac{7}{8}$ inch outside lap.
- $\frac{1}{8}$ inch inside lap.
- 5 inch travel of valve.
- $\frac{1}{16}$ inch lead in full gear.

6 use
- $\frac{3}{4}$ inch outside lap.
- $\frac{1}{16}$ inch inside lap.
- $4\frac{3}{4}$ inch travel of valve.
- $\frac{1}{8}$ inch lead in full gear.

4 use
- $\frac{1}{4}$ inch outside lap.
- $\frac{1}{4}$ inch inside lap.
- 5 inch travel of valve.
- $\frac{1}{8}$ inch lead in full gear.

Locomotives Running Express Accommodation Trains.

20 use
- $\frac{3}{4}$ inch outside lap.
- $\frac{1}{8}$ inch inside lap.
- 5 inch travel of valve.
- $\frac{1}{16}$ inch lead in full gear.

10 use
- $\frac{7}{8}$ inch outside lap.
- $\frac{1}{16}$ inch inside lap.
- $5\frac{1}{2}$ inch travel of valve.
- $\frac{1}{16}$ inch lead in full gear.

5 use
- $\frac{5}{8}$ inch outside lap.
- $\frac{3}{16}$ inch inside lap.
- $4\frac{1}{2}$ inch travel of valve.
- $\frac{1}{8}$ inch lead in full gear.

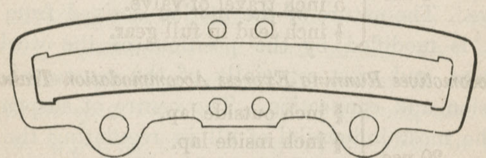
Locomotives Running Heavy Freight Trains.

19 use
- $\frac{3}{4}$ inch outside lap.
- $\frac{1}{16}$ inch inside lap.
- 5 inch travel of valve.
- $\frac{1}{16}$ inch lead in full gear.

11 use
- $\frac{5}{8}$ inch outside lap.
- $\frac{1}{8}$ inch inside lap.
- $4\frac{1}{2}$ inch travel of valve.
- $\frac{1}{16}$ inch lead in full gear.

5 use
- $\frac{1}{2}$ inch outside lap.
- $\frac{3}{16}$ inch inside lap.
- $4\frac{3}{4}$ inch travel of valve.
- $\frac{1}{16}$ inch lead in full gear.

THE LINK.



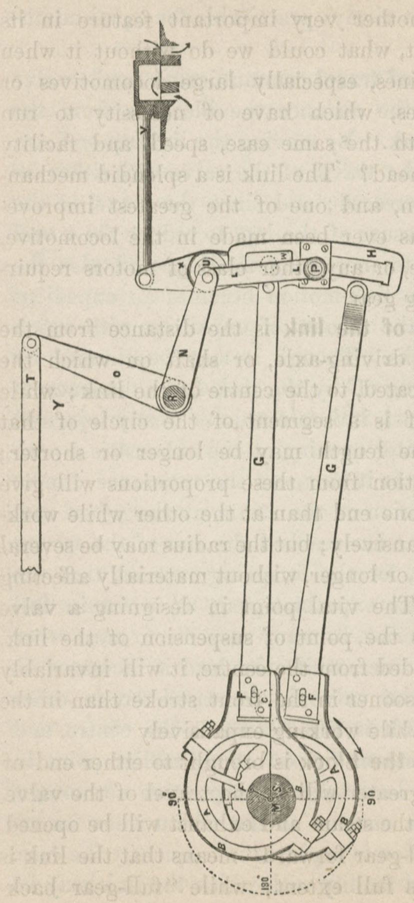
The link-motion is an arrangement of valve-gear for reversing engines and varying the rate of expansion. It consists of two eccentrics, with straps and rods. The eccentrics are so placed that when one is in the right position for the engine to move forward, the other is in the position for moving backward; and by raising or lowering the link, motion will be communicated to the valve and the engine will move backward or forward. The result of this combination is that the link receives a reciprocating motion in its centre; since, when one eccentric is moving the end of the link in one direction, the other is moving the other end in the other direction; so that the link will have nearly the same motion communicated to it as if it were suspended from a pivot at its centre.

The horizontal motion communicated to the link by the joint action of the eccentrics, is a minimum at the centre of its length, where it is equal to twice the linear advance, and it increases towards the extremities of the various periods of the block in the link, or of the link on the block, on the general principle that admission varies with the travel of the valve. The nature of the motion derived from the link is modified by the positions of the working centres, and most especially of the centres of suspension and connection. The centre of suspension is the most influential of all in regulating the admission, and its transition horizontally is much more efficacious than a vertical change of place to the same extent, inasmuch as the vertical movement of the body of the link, with the consequent slip between the link and the block, is the least possible when the suspended centre lies in the centre line of the link, and increases as the centre is moved laterally. The centre line of the link is therefore, in this respect, the most favorable location for the suspension, even

though it be not always practicable for equal admissions.

The amount of travel communicated to the valve depends upon the distance the block is from the centre of the link. By moving the link up or down on the block, the travel of the valve will either be increased or decreased; and since the travel of the valve is the measure of the lap, to reduce the travel is tantamount to increasing the lap, and also the lead. Thus the link-motion becomes an expedient for regulating the amount of expansion with which the engine works. Though it may be claimed by some that cutting off by the link has a tendency to affect the exhaust, it does not do so to any injurious extent, as the later opening of the exhaust is a positive advantage, as it balances the resistance due to the early admission of the steam at the other end, before the engine has reached the end of the stroke. It will be seen, for the foregoing reasons, that the link is a perfect expansion-gear, as, when in full stroke, it is superior, in many respects, to most other cut-off devices, since, while the lead is increased as the travel of the valve is decreased, or, in other words, as the link is lifted towards the centre, and the supply of steam cut off at an earlier point in the stroke, the lead becomes a positive advantage, as it serves as a cushion to the piston when its reciprocating motion is rapid, as is frequently the case.

The ease and facility with which the link may be



ECCENTRIC, LINK, AND VALVE MOTION.

A A, eccentrics; B B, eccentric straps; F B, angular advance; M S, main shaft or driving-axle; C, crank-pin; F F, stub-ends of eccentric rods; G G, eccentric rods; H, link; P, saddle-pin; L, lifting link; W, link block; U, rocker shaft; R, reverse shaft; N, lifting arm; O, reverse arm; T, reach rod; X, rocker arm; V, valve rod. The points 90 and 180 represent the position of the crank at full and half stroke. It will also be observed that if the reverse arm, O, is drawn back in the direction of Y, the link H will be lifted to the block W, the position of the valve will be changed, and the motion of the engine reversed.

handled is another very important feature in its favor. In fact, what could we do without it when handling engines, especially large locomotives or marine engines, which have of necessity to run backwards with the same ease, speed, and facility as they run ahead? The link is a splendid mechanical conception, and one of the greatest improvements that has ever been made in the locomotive, marine engine, or any other class of motors requiring a reversing gear.

The radius of the link is the distance from the centre of the driving-axle, or shaft on which the eccentric is located, to the centre of the link; while the link itself is a segment of the circle of that diameter. The length may be longer or shorter; but any variation from these proportions will give more lead at one end than at the other while working steam expansively; but the radius may be several inches shorter or longer, without materially affecting the motion. The vital point in designing a valve link-motion is the point of suspension of the link. If it is suspended from the centre, it will invariably cut off steam sooner in the front stroke than in the back stroke, while working expansively.

The nearer the block is brought to either end of the link, the greater will be the travel of the valve, and the more the steam and exhaust will be opened. The *term* "full-gear forward" means that the link is dropped to its full extent; while "full-gear backward" means that the link is lifted to its full extent. When the link-block stands directly under the saddle-plate, both ports are closed, and neither admission nor exhaust can take place. The distance between the block and the end of the link when in full-gear is termed the clearance.

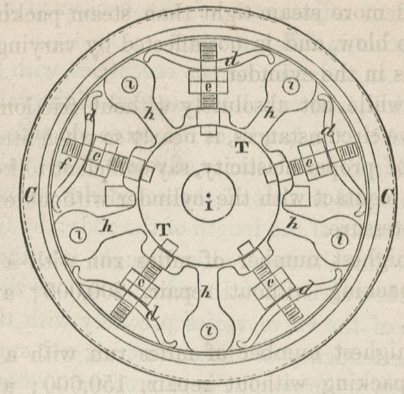
In the Walschäert link-motion, which was used on one or two of the small engines at the Centennial Exposition, the mid-gear movement was derived directly from the cross-head, while the end, or full-gear, movement was derived from a single eccentric, or a return crank, from the main crank-pin. The middle of the link is stationary, and, of itself, imparts no motion to the valve; but between the link and valve is an arrangement for imparting a reduced and reversed copy of the piston movement to the valve, which movement, being always present, modifies that of the eccentric at all points, giving it the effect of angular advance, which is not given to the eccentric in the case of the ordinary link-motion.

Lifting and stationary links.—The lifting-link is raised and lowered to effect the changes it is designed to perform; while in the stationary link the block, instead of the link, is shifted. In the stationary link but one eccentric is generally used, the throw of which corresponds to the middle of the ordinary link; for this reason, more mischief would be caused by any lost motion in the eccentric straps or other connections. Moreover, it does not allow of ready,

independent adjustment of the backward and forward motion in full gear.

The linear advance of the eccentrics, with the stationary link, is always less than that of the valve, and is effected by the length of the eccentric rods. With the shifting link, the linear advance of the valve is in all cases equal to that of the eccentrics in full gear, independently of the length of the rods; by full gear is meant that the fore-rod is brought into the centre line of the valve-rod. In other positions the linear advance of the valve varies precisely with the lead.

As the tendency of the connecting-rod angularity in a direct acting engine is to produce a *later* cut-off on the forward stroke than the amount required, and since with the link the cut-off in either stroke depends on its degree of elevation or depression, it follows that, if we suspend the link in such a manner as to cause a suitable elevation for the forward stroke, the result will be a perfectly equalized motion for the gear in question. And again, if the equalization be made applicable to all gears, then the link may be suspended at *any* point between the full forward and full back *without* an appreciable inequality appearing between the cut-offs or the exhaust closures of either stroke.



The above cut represents an end view of the spring piston packing, such as is used in locomotives. i represents the front end of piston-rod; T, piston-head; *h*, wings; *f*, studs; *e*, jam-nuts; *d*, springs; *l*, holes for follower-bolts; C, C, rings.

STEAM AND SPRING CYLINDER PACKING FOR LOCOMOTIVES.

The chief merit of steam packing is said to consist in its absence of friction, when not under pressure of steam, in descending grades and upon approaching stations.

It is also claimed for steam packing that it can be more cheaply constructed than spring packing, and, after being first put in the cylinder, requires no subsequent adjustment by the engineer.

On the other hand, it is urged for spring packing

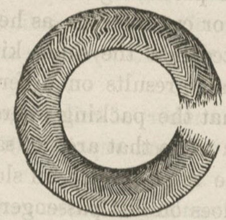
that it is more steam-tight than steam packing, less liable to blow, and is not affected by varying steam pressures in the cylinder.

And while not absolutely without friction under the above circumstances, is nearly so when fitted with springs of proper elasticity, say sufficient to keep the rings in contact with the cylinder without exerting undue pressure.

The highest number of miles run with a set of steam packing without repair, 200,000; average, 150,000.

The highest number of miles run with a set of spring packing without repair, 150,000; average, 100,000.

Setting out Spring Cylinder Packing.—Setting out spring packing in the cylinders of locomotives requires the exercise of great care and judgment, for, like *valve* setting, no general rule can be laid down—the proper adjustment must in all cases depend on the skill and intelligence of the engineer. An ignorant or careless adjustment of the packing may at any time not only materially lessen the power of the engine, but literally ruin both the packing and the cylinders. If the packing be set out too tight, the friction between the packing-rings is increased to such an extent that the power that ought to be transmitted from the pistons to the driving-wheels is wasted in overcoming the friction in the cylinders. If, on the other hand, the packing is allowed to be slack, the steam will escape and occupy the cylinder in front of the piston on the exhaust end, causing excessive cushioning, with great waste of steam and loss of power in the engine.



PACKING FOR THE PISTONS AND VALVE RODS OF LOCOMOTIVES.

There is probably no part of the locomotive more frequently out of order, or gives greater annoyance, than the piston- and valve-rod packing.

A vast deal of study and ingenuity have been applied to the removal of this annoyance, and the production of a durable piston-rod packing. Wire gauze, gum, soapstone, jute, asbestos, metallic packing, and a great variety of other materials have been tried, but without very satisfactory results.

Hemp, when properly used, serves a good purpose, as it has the advantage of always being ready and requiring no special tools to prepare it for use, nor any particular size of stuffing-box, and can be used as well by the unskilful as the skilled man; but its

usefulness is limited, particularly where steam of a high pressure is used, as it soon loses its elasticity, and, in consequence, becomes worthless.

Soapstone gives tolerably good results, and has the advantage of producing less friction, and is not so liable to flute or cut the rods as hemp. But it is not to be expected that the same kind of packing would give the same results on different roads, as it is well known that the packing wears out faster on sandy roads than those that are not sandy; nor does packing give the same service on slow freight locomotives that it does on fast passenger engines. The failure of packing to give satisfactory results in many cases is due to a want of skill and judgment on the part of the persons using it.

The softer the packing can be kept in the stuffing-boxes, the more service it will do; for when it loses its spring or elasticity, it materially interferes with the easy working of the engine, and any extra tightening has a tendency to char and render it worthless.

If the packing leaks badly around the rod after being renewed, and it is found impossible to make it steam-tight, it is always better, if time will permit, to take out one or two rings and reverse them, which will be found, in most cases, to give relief; or if it becomes necessary to tighten the packing, it is always better to do so when it is cold, or after the engine has been standing still for some time.

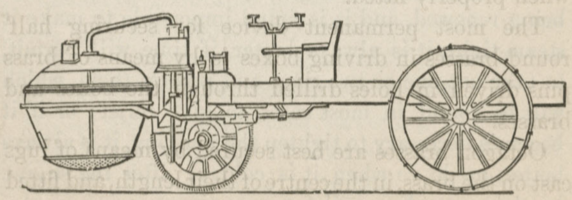
Metallic packing, for piston-rods, has been tried by a number of the principal railroads in the country; but its use has been generally abandoned on account of its results not bearing out its first costs and needed repairs.

There is at present, and always has been, a great need of a permanent and reliable piston-rod packing. Such an article would not only be productive of very economical results on railroads, but would greatly lessen the labors of engineers.

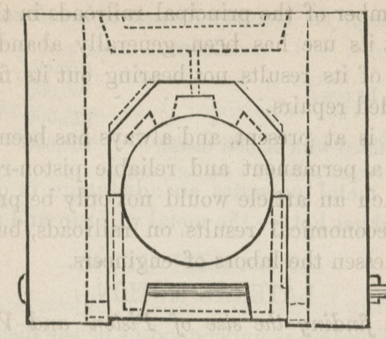
Rule for finding the size of Piston- and Valve-Rod Packing.

Measure the piston- or valve-rod; then measure the stem of the stuffing-box; divide the difference between them by two.

For example: Rod 2 inches, box 4 — packing 1 inch; rod 1 inch, box 2 — packing $\frac{1}{2}$ inch; rod $\frac{3}{4}$ inch, box $1\frac{1}{2}$ — packing $\frac{3}{8}$; rod 2 inches, box $3\frac{1}{2}$ — packing $\frac{3}{4}$; rod $1\frac{1}{2}$ inches, box 4 inches — packing $1\frac{1}{4}$.



CUGNOT'S LOCOMOTIVE—1769.



BRASSES FOR DRIVING AXLES OF LOCOMOTIVES.

The importance of good workmanship in fitting the brasses in the boxes of driving axles is well known to railway mechanics, because unless thoroughly fitted they are liable to become loose and give trouble. Hexagon-shaped brasses generally give better results than either half-round or gib brasses, when properly fitted.

The most permanent device for securing half round brasses in driving boxes is by means of brass pins driven in holes drilled through the boxes and brasses.

Octagon brasses are best secured by means of lugs cast on the brass, in the centre of their length, and fitted into recesses cast in the box. This is considered better than a flange on the ends, as the thickness of the brass can be seen without taking it out.

Best Milage for Driving Brasses before Becoming Loose.

	Highest.	Lowest.
Half-round Brasses, ...	120,000	10,000
Octagon "	125,000	25,000
Brass gibs, fitted with Babbit metal, .	100,000	85,000

Babbit metal possesses an advantage in case the box should get hot, — the metal will run and prevent cutting.

LATERAL MOTION.

Lateral motion is understood to be the distance or the clearance between the rails and flanges of locomotive and truck wheels, and which in general practice is about ⅜ of an inch for the forward driving- and truck-wheels, and about ⅝ for the rear drivers. The difference in gauge for front and rear drivers is to allow for the radius of the curve, and is of great importance, especially in the case of ten-wheeled engines, or those having an extended wheel-base.

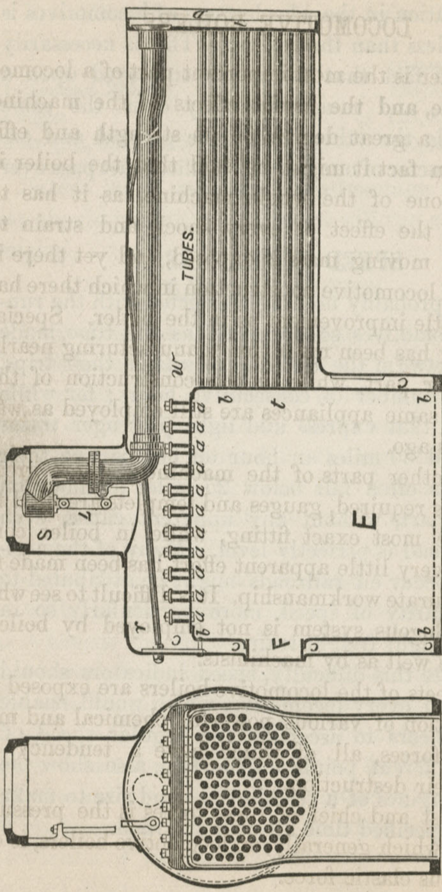
A liberal allowance of lateral motion is beneficial, as it lessens the friction, more especially in curving, and saves a large amount of power in drawing trains; but wide lateral motion involves a certain amount of danger, as there is a liability of breaking the flanges when thrusted against the rail, or forcing the wheels off the axles when striking guard-rails and frogs. Wide lateral motion is also attended with too much oscillation of the car body for safety, when running around sharp curves at a high speed.

The variation in the wheel-gauge of locomotives is immensely less than that of cars. This is necessarily so from the fact that the one is employed upon a fixed gauge, and runs repeatedly over the same track; while the others, from the general and extended character of our railway traffic, must pass over other lines.

SPEED INDICATORS.

There is probably nothing connected with the running of locomotives so uncertain as the time made by trains between the different points on their trips, or for any number of consecutive hours; for while it is known that express and light passenger trains often exceed 30 miles an hour on one part of their trip, they as often fall below 25 miles an hour on the other part, without any apparent cause, even where the road is perfectly level. Many of the accidents that occur on railroads might be attributed to this irregularity of speed, more particularly so in the case of light freight trains.

To obviate this difficulty, speed indicators should be placed on every locomotive, which would enable railroad officers to ascertain the regular speed of trains at different points on the trip, also show the ability of engines of a certain class and size to make a uniform specified time all over the road.



STRAIGHT LOCOMOTIVE BOILER.

E, fire-box; F, fire-hole; *c, c, c*, water space; *t, t*, tube sheets; *a, a*, crown bars; *r*, steam-room; *w*, water; S, steam-dome; T, throttle-pipe; L, throttle-lever; K, steam-pipe.

LOCOMOTIVE BOILERS.

The boiler is the most important part of a locomotive engine, and the useful effects of the machine depend, in a great degree, on its strength and efficiency. In fact it might be said that the boiler is the backbone of the whole machine, as it has to withstand the effect of every shock and strain to which the moving mass is exposed, and yet there is no part of locomotive construction in which there has been so little improvement as in the boiler. Special machinery has been made for manufacturing nearly every other part, while in the construction of the boiler the same appliances are still employed as was used years ago.

In all other parts of the machinery where great strength is required, gauges and templets are used to insure the most exact fitting, while in boiler construction very little apparent effort has been made to secure accurate workmanship. It is difficult to see why some analogous system is not employed by boiler-makers as well as by machinists.

The sheets of the locomotive boilers are exposed to the operation of various powerful chemical and mechanical forces, all of which have a tendency to hasten their destruction.

The first and chief of these forces is the pressure of steam, which generally, on locomotive boilers, is of tremendous elastic force.

Then there are the strains caused by the jarring of the locomotive, especially on some roads, and at some seasons of the year, when the earth is loosened by the breaking up of the frost, and the sleepers and rails are in a shaky condition.

Next the oxidation caused by the ingredients in the water, the mechanical force of the water itself, and its impact against the walls of the boiler, the injurious effects of which must be severe.

All these strains combined affect the several parts of the boiler — the intense heat rendering the material more crystalline and more liable to fracture; the continual jar having a tendency to loosen the rivets and weaken the whole structure.

A boiler may be abundantly strong, but insufficiently stiff; whereas, in a locomotive boiler, above all others, identity of form is of great importance, as, besides the ordinary contingencies of overstrained joints and leakage, resulting from change of form, there are, unavoidably, connections and attachments to be made here and there which can only be maintained in good order under superior conditions of stability of parts.

A locomotive boiler must evidently possess other features of strength than those required in a mere steam generator. However strongly and independently the frames of the engines may be constructed, the simple holding of the boiler in place upon them necessitates considerable extra stiffness in the latter.

The boiler answers, in part, as a framing, and not only stiffens the structure, preventing side or lateral flexure, but sustains the entire fore and aft strain of the engine, as developed in cylinders, since the centre line of the boiler is so far above that of the cylinder, giving the latter so much leverage that the strain tends to pry the boiler asunder at the junction of the waist with the fire-box.

Regarding the locomotive-boiler as a cylinder with flat ends, the greatest strain falls necessarily upon the longitudinal seams, and the least upon the curvilinear seams at and between the ends of the boiler.

The longitudinal seams, therefore, should in all cases be double-riveted, while for curvilinear seams, bearing only half the strain that is upon the other, the single-riveted seam is sufficient, being proportionably stronger, with respect to strains arising from steam pressure, than the other.

Steel plates are now very generally used, and their importance as a material for the construction of locomotive boilers is fully established, as is shown by the successful results of careful experimental investigations. Steel is always crystalline in its nature. Whatever the jarring and straining to which it is exposed, its quality cannot be altered in that respect; while its toughness, notwithstanding its crystalline structure, is to wrought-iron as two to four, and in some cases more than that.

The thickness of iron plates generally used for locomotive boilers ranges from $\frac{3}{8}$ to $\frac{5}{8}$; but when steel is used, this thickness can be reduced $\frac{1}{16}$, or even $\frac{1}{8}$, as steel plates $\frac{1}{4}$ inch thick, for boilers 48 inches in diameter, are perfectly safe at 150 pounds' pressure per square inch, besides affording increased facilities for the transmission of heat from the fire to the water.

It is evident then that in case no more steam pressure is carried, the repair expenses of steel boilers, as compared with iron of equal section, will be decreased, not only in proportion to their superior strength, but in a great proportion by reason of their elasticity, hardness, granular construction, and resistance to corrosion.

And if proportionately higher steam pressure is carried, so that the relation of strength to strain is the same as in iron boilers, the repair expenses will still be decreased by reason of the last-named qualities of steel.

What is true as to the expenses of maintenance is true as to safety. Recent discussions, and recently compiled facts on the subject of boiler explosions, show quite conclusively that the larger proportion of these casualties result simply from the want of proper strength in the boiler.

Recent experiments on standard kinds of iron plates showed a mean strength of 49,215 pounds to the square inch, while experiments made at the same time on steel plates showed a mean strength of 85,275 pounds. The difference in the weight of iron and

steel plates of the same dimensions is not great enough to be of practical importance. Other things being equal, therefore, a steel boiler is 73 per cent. stronger than an iron boiler.

PROPORTIONS OF THE LOCOMOTIVE BOILER, FROM THE BEST MODERN PRACTICE.

Boiler sheets, best cold-blast charcoal iron, $\frac{3}{8}$ inch thick, or best homogeneous cast-steel, $\frac{5}{16}$ inch thick, or horizontal seams and junction of waist in fire-box double-riveted.

Waist, formed of two sheets rolled in the direction of the fibre of the iron or steel, one longitudinal seam in each, located above the water-line.

All longitudinal seams double riveted; curvilinear seams single riveted.

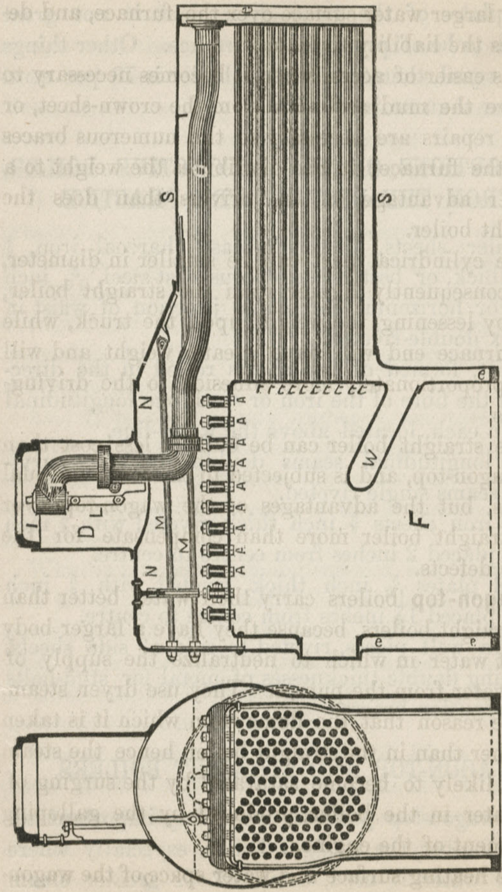
All iron sheets $\frac{3}{8}$ inch thick riveted with $\frac{3}{4}$ inch rivets, placed 2 inches from centre to centre.

Steel plates $\frac{5}{16}$ inch thick, riveted with $\frac{5}{8}$ inch rivets, placed $1\frac{7}{8}$ inches from centre to centre.

Extra welt pieces, riveted to side of side sheets, providing double thicknesses of metal for stud-bolts and expansion braces.

WAGON-TOP AND STRAIGHT BOILERS.

The wagon-top possesses some very important advantages over the straight boiler, especially where impure water is used, as it affords greater steam



WAGON-TOP LOCOMOTIVE BOILER.

F, furnace; *e*, *e*, *e*, *e*, water space; *t*, tubes; S, S, shell; M, M, braces; A, A, crown bars; N, N, steam room; D, steam dome; I, dome top; L, throttle lever; O, steam-pipe.

room, larger water surface over the furnace, and decreases the liability to foam.

It is easier of access when it becomes necessary to remove the mud and scale from the crown-sheet, or when repairs are necessary to the numerous braces over the furnace; it also distributes the weight to a greater advantage on the drivers than does the straight boiler.

The cylindrical part can be smaller in diameter, and consequently lighter than the straight boiler, thereby lessening the weight upon the truck, while the furnace end will have greater weight and will give proportionately more adhesion to the driving-wheels.

The straight boiler can be built at less cost than the wagon-top, and is subjected to the fewer unequal strains, but the advantages of the wagon-top over the straight boiler more than compensate for the above defects.

Wagon-top boilers carry their water better than the straight boilers, because they have a larger body of hot water in which to neutralize the supply of cold water from the pumps. They use dryer steam, for the reason that the dome from which it is taken is higher than in the straight boiler, hence the steam is less likely to become saturated by the surging of the water in the boiler, produced by the galloping movement of the engine.

The heating surface and water space of the wagon-top is greater than that of the straight boiler, with about the same amount of steam room; and, in ascending high grades, the wagon-top possesses great advantages over the straight boiler on account of the great body of hot water carried. It is generally unnecessary to pump where the engine is performing her hardest labor.

Two domes are preferable to one on boilers with limited steam space, and on boilers using impure water, provided steam is taken from the two domes, as there is less variation in the water level, and dryer steam is obtained in the cylinders.

The crown or upper sheet of the wagon-top is necessarily weaker than that of the straight boiler on account of its large radius. This is often still further weakened by cutting a hole for the dome in it, half as large as the diameter of the cylinder of the boiler. A single-riveted dome, as ordinarily made, does not restore much above half the strength thus taken away.

THE EVAPORATIVE POWER OF LOCOMOTIVE BOILERS.

The quantity of water evaporated by a boiler in a given time depends not only on the heating surface, grate surface, and draft area, but also upon the conducting powers of the boiler and the quantity of air which passes through the furnace in a given time.

A locomotive boiler, for instance, burning 10 pounds of coal on each square foot of grate-surface in an hour, will evaporate about 9 pounds of water for each pound of coal under the most favorable conditions. The same boiler running at high speed, and burning 75 pounds of coal on each square foot of grate-surface, will evaporate 7 pounds of water for each pound of coal burned.

The total quantity evaporated in an hour in the first case will be $10 \times 9 = 90$ pounds of water for each square foot of grate-surface; and in the second case, the same boiler, under a forced draft, will evaporate $75 \times 7 = 525$ pounds of water in one hour. Here there is a vast difference in the total amount of evaporation; but each pound of coal, under the forced draft, produces less steam, in the proportion of 7 to 9 pounds, so that while the economy of fuel in one sense is less, the total amount of work done by the same boiler in the same time is very much greater with the higher rate of combustion.

There are probably no phenomena connected with the generation and utilization of steam so imperfectly defined, either theoretically or practically, at present, as those connected with the quantity of air which passes through the furnaces of boilers under varying conditions of draft.

It has been generally assumed from the experiments of scientists that in ordinary practice double the amount of air necessary for complete combustion passes through the furnace. Hence all attempts to reduce the laws of evaporation of boilers to fixed and definite rules of practice for all conditions of draft, have thus far been based on assumptions which have no definite and precise foundation in practice.

Experiments are greatly needed to determine the rate of combustion for varying conditions of draft, as well as the quantity of air actually drawn through the furnaces under these varying rates of combustion. Such determinations are necessary in order to establish the corresponding temperatures of the furnaces and the gaseous products of combustion, and from these the transfer of heat by radiation and contact in the furnaces and flues respectively.

HEATING SURFACE, STEAM ROOM, AND WATER SPACE IN LOCOMOTIVE BOILERS.

The importance of *extent* in the surface of water, in a boiler, consists in the facility afforded for the ready egress of the steam, as evolved by the heating surface. The most satisfactory results are obtained when the water space is equal to the heating surface, and any deviations from these proportions are always attended with some disadvantage, though doubtless unappreciable until the disproportion arising from the increase of heating surface becomes very great.

The engine whose steaming capacity is worked nearly or quite to its maximum while hauling trains

upon a level, will require an extra strain to furnish the steam over the grade, from which few roads can claim an absolute immunity. The advantage of surplus steam space can hardly be over-estimated, especially in handling heavy trains.

In the case of locomotives it is almost impossible to fix any ratio whatever between the water space and heating surface, since the former, of necessity, is limited, and every additional row of tubes, to increase the heating surface, reduces the area of the water space.

So with the steam room, to secure dryness of steam and steadiness of action, large space is desirable; but it is limited by the same considerations that restrict the water space — though the evils arising from limited steam room are relieved, to a certain extent, by the use of domes and the dry pipe.

The only practical rule for the construction of locomotive boilers, with respect to water space and steam room, seems to be, for a given heating surface, to secure as large a water and steam space as possible — the larger the better — within the limits imposed by restriction in the size of the boiler.

Very excellent performances have been obtained from boilers with an area of water surface $\frac{1}{13}$ that of the heating surface, and a steam room about one cubic foot to one square foot of water surface.

HEATING SURFACE TO GRATE SURFACE IN STEAM BOILERS.

Diameter of cylinder, ...	16 inches.
Stroke, ...	24 "
Heating surface in fire-box, . . .	100 square feet.
" " " tubes, . . .	862 " "
Total heating surface, ...	962 " "
Area of grate, ...	24 " "

40.1 sq. feet of heating surface to 1 foot of grate surface.

Diameter of cylinder, ...	15 inches.
Stroke, ...	22 "
Heating surface in fire-box, . . .	85 square feet.
" " " tubes, . . .	645 " "
Total heating surface, ...	730 " "
Area of grate, ...	11 " "

66.4 sq. feet of heating surface to 1 sq. foot of grate surface.

Diameter of cylinder, ...	18 inches.
Stroke, ...	22 "
Heating surface in fire-box, . . .	116 square feet.
" " " tubes, . . .	813 " "
Total heating surface, ...	929 " "
Area of grate, ...	15 " "

62 sq. feet of heating surface to 1 sq. foot of grate surface.

Rule for finding the Heating Surface in Locomotive Boilers.

Multiply the length of the sides and ends of the fire-box by the height in inches; multiply the length of the crown-sheet by its width in inches. Add these products together, and subtract the combined area of all the tubes and fire-door; divide the remainder by 144, and the quotient will be the heating surface in the fire-box in square feet.

Rule for finding the Heating Surface in the Tubes of Locomotive Boilers.

Multiply the circumference of one tube in inches by its length in inches; multiply that product by the whole number of tubes, and divide this product by 144, which will give the heating surface in the tubes in square feet. (See Table of Superficial Areas of Tubes.)

Rule for finding the Heating Surface in Stationary Boilers.

Multiply the length of the boiler in inches by ⅔ the circumference in inches; multiply the circumference of all the tubes or flues in inches by their length in inches. Add these two products and the areas of the ends in square inches together, and divide by 144. The quotient will be the number of square feet of heating surface. To find the horse-power, divide by 14 (14 square feet being a fair allowance for horse-power in steam-boilers).

PUNCHED AND DRILLED HOLES FOR THE SEAMS OF LOCOMOTIVE BOILERS.

Punching rivet holes, according to Fairbairn's experiments, is in itself a cause of weakness. Not only is the section of the plate in the line of strain reduced by the area of the holes, but the plate between the holes is not so strong per square inch as the solid plate.

The excessive strain of the punch appears to disturb the molecular arrangement of the metal, and to start fractures which, in case of stay-bolts, often radiate in every direction, allowing corrosion to take place, and ultimately causing the bolts to pull out of the plate.

In eight experiments by Fairbairn, the highest strength of plate experimented upon was 61,579 pounds, and the lowest 43,805 pounds per square inch; but with the same plates after punching, the strength per square inch varied between 45,743 pounds and 36,606 pounds. The average of the two experiments, therefore, showed a loss of 10,896 pounds per square inch, due to the jar and strain of punching, in addition to the loss of section through the holes.

In the process of punching, through the ignorance or neglect of workmen, the holes do not come right by sometimes half their diameter, and are then drifted until the sheet is fractured, and the material partly destroyed. This habit cannot be too much reprehended, and the use of drifts, although considered indispensable by many good boiler-makers, is productive of great evils.

The result is when the rivets are driven it is almost impossible to make them fill the holes, and consequently an undue strain will come upon some of the rivets, while upon others there will be very little strain. In that case there is danger of shearing off the rivet upon which the extra strain comes, and bringing a strain upon the adjoining holes, and thus starting a rupture, which will ultimately result in the destruction of the boiler.

The danger arising from this cause of rupture can be easily avoided by drilling, as the holes can be made to match exactly if the plates are drilled together, and therefore each rivet will do its due proportion of the work, and no greater strain will be thrown upon one than the others.

Recent experiments authorized by the U. S. Government at the Washington Navy Yard establish the fact that drilled holes for boiler seams are 6 *per cent.* stronger than holes that are punched.

In view of the above conclusions, it is very evident that the rivet holes for all longitudinal seams of steam boilers should be drilled. The curvilinear seams, being subjected to only about half the strain of the longitudinal, might be punched.

It is also worthy of note that, while the punched plate is weaker than the drilled plate, the rivets in the punched holes do not shear so easily as those in the drilled holes. This is probably due to the edges of the drilled holes being sharper and more compact, and consequently more capable of shearing than the edges left by a punch.

Welding the seams of locomotive boilers, if practical, would be of great advantage, since the welded joint is practically twice as strong as the riveted joint; and since twice as much steam pressure is exerted on the longitudinal seams of the cylinder of a boiler as on its circular seams, the right proportion of strength would be preserved by welding the former and riveting the latter.

The following advantages would be acquired by welding the seams of locomotive boilers: — 1st. It would cheapen the process of construction, by saving much of the time occupied in riveting, and all that consumed in caulking. 2d. The full strength of the plates being preserved, a thinner material would suffice, and, as a result, less dead weight would have to be transported. 3d. Double the pressure could be carried without increasing the weight of the boiler. 4th. There would be no double thickness of plate to promote unequal expansion. 5th. Where the greatest strain would occur, there would be no laps or joints, and consequently there would be no leakage.

MACHINE AND HAND RIVETING FOR LOCOMOTIVE BOILERS.

In the process of hand riveting, the heads are rarely finished till the iron is cool enough to crystallize or crack under the head by the heavy blows of the hammer, and if the material be not of superior quality, will frequently snap off under rough usage.

Not so in machine riveting. As the piston is not limited in its movements, it will follow the rivet home, drawing the plates well together, filling the holes, and making the work equally good, whether the rivet is a half inch too long or a half inch too short, thus accomplishing what no workman could possibly do.

As the riveting is done with a blow, and not by squeezing, the iron of the rivet is given no time to cool, by contact with the sheet, before it is forced into every crevice, and the hole completely filled.

The heading is done on the "capping" system, thus gathering the metal together instead of scattering it, as is the case with the hand hammer.

The rivets driven by the Piston machine show the hole to be well filled all around, and not stretched to any appreciable extent, (not more so than in hand riveting,) while the rivet and plates are left soft and free from any crystallization.

The shearing strain is less on machine-riveted joints than on those riveted by hand, on account of the compactness of the rivets in the holes, and the great friction between the sheets at the lap, induced by the power of the machine.

Another great advantage of steam riveting is its quickness and cheapness.

COMPARATIVE STRENGTH OF SINGLE AND DOUBLE RIVETED BOILER SEAMS.

On comparing the strength of plates with their riveted joints, it will be necessary to examine the sectional areas, taken in a line through the rivet-holes with the section of the plates themselves.

It is perfectly obvious that in perforating a line of holes along the edge of a plate, we must reduce its strength; it is also clear that the plate so perforated will be to the plate itself nearly as the areas of their respective sections, with a small deduction for the irregularities of the pressure of the rivets upon the plate; or, in other words, the joint will be reduced in strength somewhat more than in the ratio of its section through that line to the solid section of the plate.

It is also evident that the rivets cannot add to the strength of the plates, their object being to keep the two surfaces of the lap in contact.

When this great deterioration of strength at the joint is taken into account, it cannot but be of the greatest importance that in structures subjected to

such violent strains as boilers, the strongest method of riveting should be adopted. To ascertain this, a long series of experiments were undertaken by Mr. Fairbairn.

There are two kinds of lap-joints,—those said to be single riveted (Fig. 1), and those which are double riveted (Fig. 2). At first, the former were almost universally employed, but the greater strength of the latter has since led to their general adoption for all boilers intended to sustain a high steam pressure.

A riveted joint generally gives way either by shearing off the rivets in the middle of their length, or by tearing through one of the plates in the line of the rivets

In a perfect joint, the rivets should be on the point of shearing just as the plates were about to tear; but in practice, the rivets are usually made slightly too strong. Hence, it is an established rule to employ a certain number of rivets per lineal foot.

If these are placed in a single row, the rivet holes so nearly approach each other that the strength of the plates is much reduced; but if they are arranged in two lines, a greater number may be used, and yet more space left between the holes, and greater strength and stiffness imparted to the plates at the joint.

Taking the value of the plate before being punched at 100, by punching the plate loses 44 per cent. of its strength, and, as a result, single-riveted seams are equal to 56 per cent., and double-riveted seams to 70 per cent. of the original strength of the plate.

It has been shown by very extensive experiments at the Brooklyn Navy Yard, and also at the Steven's Institute of Technology, Hoboken, N. J., that double-riveted seams are from 16 to 20 per cent. stronger than single-riveted seams — the material and workmanship being the same in both cases.

Fig. 1.

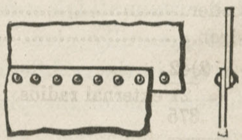
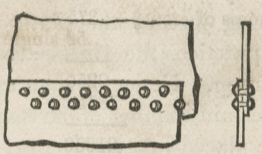


Fig. 2.



Taking the strength of the plate at . .	100
The strength of the double-riveted joint would then be	70
And the strength of the single-riveted joint would be	56

Rule for finding safe Working Pressure of any Boiler.

Multiply the thickness of iron by .56, if single-riveted, and .70 if double-riveted; multiply this product by 10,000 (safe load); then divide this last product by the external radius (less thickness of iron): the quotient will be the safe working pressure in pounds per square inch.

EXAMPLE.

Diameter of boiler.............................. 42 inches.
Thickness of iron.............................. $\frac{3}{8}$ "

2)42
21 external radius.
.375
20.625 internal radius.

Thickness of iron $\frac{3}{8}$ = .375
.56 single riveted.
2250
1875
.21000
10000 safe load.

20.625) 2100.00000
101.81 pounds safe working pressure.

In the above rule 50,000 pounds per square inch are taken as the tensile strength of boiler iron, and one-fifth of that, or 10,000, as the safe load. Hence five times the safe working pressure, or 50,000 pounds, would be the bursting pressure.

Rule for finding the Safe Working Pressure of Steel Boilers.

Multiply thickness of steel by .56 if single riveted, and .70 if double riveted; multiply this product by 16,000 (safe load); then divide this last product by the external radius (less thickness of steel): the quotient will be the safe working pressure in pounds per square inch.

EXAMPLE.

Diameter of boiler.............................. 44 inches.
Thickness of steel.............................. $\frac{1}{4}$ "

```
 2)44
   22 external radius.
   .25
 -----
 21.75 internal radius.
Thickness of steel 1/4 = .25
                    .70 double riveted.
                   ----
                   .175
                   16000
                  -------
                  1050000
                  175
                  -------
        21.75)2800.000
              128.73 safe working
                       pressure.
```

80,000 being taken, in the above rule, as the tensile strength of steel, and one-fifth of that, or 16,000, as the safe load. Hence 80,000 would be the bursting pressure.

Rule for finding the Safe External Pressure on Boiler Flues.

Multiply the square of the thickness of the iron by the constant whole number, 806,300; divide this product by the diameter of the flue in inches; divide the quotient by the length of the flue in feet; divide this quotient by 3. The result will be the safe working pressure.

EXAMPLE.

Diameter, 13 inches.
Thickness, $\frac{3}{8}$ of an inch.

$\frac{3}{8}$ square $= \frac{9}{64}$

```
 13 diameter.
 10 length.
----
130
  3
----
390
```

$\frac{9}{64} \times 806{,}300 = \frac{7256700}{64} \div 390 = \frac{7256700}{24960} = 290.73$ safe external pressure.

When pressure is exerted within a tube or cylinder, the tube can only give way by the metal being torn asunder; and the tendency of the strain is to cause the tube to assume the true cylindrical form. — the form of greatest resistance.

But when pressure is exerted on the *outside* of a tube, the tendency of that pressure is to crush or flatten the tube.

It is a well-known fact that iron of any strength, when formed into a tube, will bear a much greater strain to tear it asunder, if that pressure be applied *internally*, than it will bear without crushing in when applied *externally*.

It is also well known that a thin iron hoop will resist a large amount of tearing force; but if that same hoop be placed as a prop under the weight exerted to tear it apart, it would be flattened and crushed out of form.

The inner tubes of boilers are nothing more or less than a series of props; but in the case of locomotive boilers the diameter of the tubes is so small that it is almost impossible to *crush* them.

DEFINITIONS AS APPLIED TO BOILERS AND BOILER MATERIALS.

Tensile strength is the absolute resistance which a body makes to being torn apart by two forces acting in opposite directions.

Working Strength.—The term "working strength" of materials is a certain reduction made in the estimate of the strength, so that when the instrument or machine is put to use it may be capable of resisting a greater strain than it is expected on the average to sustain.

Safe Working Pressure, or Safe Load.—The safe working pressure of steam boilers is generally taken as $\frac{1}{5}$ of the bursting pressure, whatever that may be.

Elasticity is that quality which enables a body or boiler to return to its original form after having been distorted or stretched by some extreme force.

EXPLANATION OF TABLE OF BOILER PRESSURES ON FOLLOWING PAGES.

The horizontal column on top of the page, $\frac{3}{8}$, 00, 0, 1, etc., represents the number of the steel.

The decimals, in the second horizontal column, are equal to the fractional parts of an inch in the third.

The vertical column on the left hand side is the diameters in inches. All the other columns represent pounds pressure per square inch.

Example. — 24-inch diameter, $\frac{3}{8}$ steel, 289.03 pounds per square inch.

Rule for finding the Aggregate Strain caused by the Pressure of Steam on the Shells of Locomotive Boilers.

Multiply the circumference in inches by the length in inches; multiply that product by the pressure in pounds per square inch. The result will be the aggregate pressure on the shell of boiler.

EXAMPLE.

Diameter of boiler....................	42 inches.
Circumference of boiler..............	131.9472 "
Length "	10 feet, or 120 "
Pressure "	125 lbs.

$$\frac{131.9472 \times 120 \times 125}{2000} = 1{,}979{,}208 \text{ pounds, or } 989 \text{ tons.}$$

TABLE

OF SAFE INTERNAL PRESSURES FOR STEEL BOILERS.

Birmingham Wire Gauge.		$\frac{3}{8}$	00	0	1	2
Thickness of Steel.		.375 $\frac{3}{8}$	.358 $\frac{3}{8}$ Scant.	.340 $\frac{11}{32}$	.300 $\frac{5}{16}$	.284 $\frac{9}{32}$
	In.	lbs. per sq. in.				
External Diameter.	24	289.03	275.52	261.26	229.74	217.19
	26	266.13	253.73	240.31	211.65	200.08
	28	246.66	235.13	223.01	196.20	185.45
	30	229.74	219.00	207.80	182.85	172.99
	32	215.04	205.06	194.15	171.21	161.91
	34	202.10	192.74	182.85	160.95	152.22
	36	190.63	181.82	172.50	151.86	143.23
Longitudinal Seams, Single Riveted.	38	180.40	172.06	163.25	143.74	135.96
	40	171.21	163.30	154.95	136.44	129.06
	42	162.90	155.39	147.45	129.85	122.83
	44	155.37	148.21	140.66	123.87	117.17
	46	148.50	141.66	134.43	118.41	112.01
	48	142.22	135.67	128.75	113.41	107.29
	50	136.44	130.17	123.53	108.82	100.03
	52	131.12	125.09	118.72	104.59	98.95
	54	126.19	120.39	114.26	100.67	95.24
	56	121.62	116.04	110.13	97.03	91.81
	58	117.37	111.99	106.29	93.65	88.61
	60	113.41	108.21	102.71	90.50	85.63
	62	109.71	104.68	99.36	87.55	82.89
	64	106.24	101.37	96.22	84.79	80.23
	66	102.98	98.26	93.27	82.20	77.77
	68	99.92	95.34	90.32	79.76	75.47
	70	97.03	92.59	87.89	77.43	73.29
	72	94.31	89.99	85.42	75.29	71.24
	74	91.74	87.81	83.09	73.24	69.30
	76	89.30	85.21	80.89	71.29	67.46
	78	86.99	83.01	78.79	69.45	65.72
	80	84.79	80.91	76.81	67.70	64.07

TABLE—(*Continued*)

OF SAFE INTERNAL PRESSURES FOR STEEL BOILERS.

Birmingham Wire Gauge.		3	4	5	6	7	8
Thickness of Steel.		.259 $\frac{1}{4}$ Full.	.238 $\frac{1}{4}$ Scant	.220 $\frac{7}{32}$	.203 $\frac{6}{32}$ Full	.180 $\frac{6}{32}$ Sc't.	.165 $\frac{5}{32}$ Full
	In	lbs. per sq. in.					
External Diameter.	24	197.63	181.13	167.33	154.18	136.44	124.91
	26	182.13	167.09	154.24	142.13	125.80	115.10
	28	168.88	154.95	143.04	131.83	116.70	106.85
	30	157.42	144.45	133.36	122.92	108.82	99.65
	32	147.42	135.29	124.91	115.14	101.94	93.36
	34	138.60	127.22	117.47	108.28	95.88	87.81
Long. Seams, Single Riveted.	36	130.80	120.05	110.86	102.20	90.50	82.89
	38	123.82	113.65	104.96	96.76	85.69	78.49
	40	117.55	107.90	99.65	91.81	81.37	74.53
	42	111.40	102.71	94.85	87.45	77.46	70.95
	44	106.71	97.99	90.50	83.44	73.91	67.70
	46	102.04	93.68	86.53	79.78	70.67	64.74
	48	97.74	89.74	82.89	76.43	67.70	62.02
	50	93.07	86.11	79.54	73.35	64.97	59.12
	52	90.15	82.77	76.46	70.50	62.45	57.22
	54	86.78	79.68	73.60	67.87	60.13	55.09
	56	83.65	76.09	70.95	65.43	57.97	53.11
	58	80.74	74.14	68.49	63.16	55.96	51.27
	60	78.02	71.62	66.19	61.07	54.04	49.55
	62	75.49	69.32	64.04	59.06	52.32	47.94
	64	73.11	67.13	62.02	57.20	50.68	46.43
	66	70.88	65.09	60.13	55.45	49.14	45.02
	68	68.77	63.16	58.35	53.52	47.68	43.69
	70	66.79	61.28	56.67	52.27	46.31	42.44
	72	64.92	59.76	55.09	50.81	45.02	41.25
	74	63.16	58.00	53.59	49.43	43.80	40.13
	76	61.48	56.47	52.17	48.12	42.64	39.07
	78	59.90	55.01	50.83	46.88	41.54	38.06
	80	58.39	53.63	49.55	45.65	40.50	37.11

TABLE—(*Continued*)

OF SAFE INTERNAL PRESSURES FOR STEEL BOILERS.

Birmingham Wire Gauge.		3/8	00	0	1	2
Thickness of Steel.		.375 3/8	.358 3/8 Scant.	.340 11/32	.300 5/16	.284 9/32
	In.	lbs. per sq. in.				
External Diameter.	24	361.29	344.40	326.58	287.23	271.49
	26	332.67	317.24	300.78	264.56	250.14
	28	308.25	293.91	278.77	237.95	231.90
	30	287.18	273.48	259.75	228.57	216.14
	32	268.80	256.34	243.16	214.01	202.39
Longitudinal Seams,	34	252.63	240.93	228.57	201.19	190.28
	36	238.24	227.27	215.62	189.83	179.54
Double Riveted.	38	225.50	215.08	204.07	179.67	169.95
	40	214.01	204.13	193.69	170.55	161.28
Curvilinear Seams,	42	203.63	194.24	184.31	162.31	153.54
	44	194.21	185.26	175.80	154.83	146.47
Single Riveted.	46	181.21	177.08	168.04	148.01	140.02
	48	177.77	169.55	160.94	141.77	134.12
	50	170.55	162.71	154.41	136.03	128.69
	52	163.90	156.40	148.01	130.73	123.68
	54	157.74	150.49	142.83	125.84	119.05
	56	152.03	145.05	137.61	121.29	114.76
	58	146.72	139.99	132.86	117.01	110.76
	60	141.77	135.26	128.38	113.13	107.03
	62	137.14	130.85	124.20	109.44	103.55
	64	132.80	126.74	120.27	105.99	100.29
	66	128.73	122.83	116.53	102.75	97.22
	68	124.90	119.18	113.13	99.70	94.34
	70	121.29	115.74	109.86	96.85	91.62
	72	117.89	112.49	106.78	94.11	89.05
	74	114.67	109.42	103.87	91.55	86.63
	76	111.62	106.51	101.11	89.12	84.33
	78	108.73	103.76	98.49	86.72	82.15
	80	105.99	101.14	96.01	84.63	80.08

TABLE—(*Continued*)

OF SAFE INTERNAL PRESSURES FOR STEEL BOILERS.

Birmingham Wire Gauge.		3	4	5	6	7	8
Thickness of Steel.		.259 1/4 Full.	.238 1/4 Scant	.220 7/32	.203 6/32 Full	.180 6/32 Sc't.	.165 5/32 Full
	In.	lbs. per sq. in.					
External Diameter.	24	247.06	226.62	209.16	192.72	175.63	156.14
	26	227.67	208.87	192.80	177.66	157.25	143.98
	28	211.10	193.69	178.80	164.78	145.87	133.57
	30	196.78	180.57	166.71	153.65	136.03	124.57
	32	184.28	169.75	156.14	143.92	127.43	116.70
Long. Seams,	34	173.27	159.06	146.84	135.35	119.85	109.77
	36	163.50	150.07	138.58	127.75	113.13	103.61
Double Riveted.	38	154.73	142.07	131.20	120.95	107.12	98.11
	40	146.94	134.88	124.57	114.84	101.71	93.16
Curvil. Seams,	42	139.85	128.38	118.57	109.32	96.82	88.69
	44	133.42	122.48	113.13	104.30	92.39	84.64
Single Riveted.	46	127.55	117.10	108.16	99.73	88.34	80.92
	48	122.18	112.17	103.61	95.54	84.63	77.53
	50	117.24	107.64	99.43	91.68	81.22	74.41
	52	112.69	103.43	95.53	88.13	78.07	71.53
	54	108.47	99.60	92.00	84.84	75.16	68.86
	56	104.56	96.01	88.69	81.79	72.46	66.39
	58	100.92	92.67	85.61	78.95	69.95	64.08
	60	97.53	89.56	22.74	76.26	67.60	61.60
	62	94.36	86.65	80.11	73.17	65.44	59.93
	64	91.38	83.98	77.53	71.52	63.35	58.04
	66	88.59	81.36	75.16	69.32	61.42	56.28
	68	85.97	78.95	72.94	67.23	59.60	54.61
	70	83.49	76.68	70.84	65.34	57.89	53.05
	72	81.16	74.53	68.86	63.51	56.28	51.56
	74	78.95	72.50	66.72	61.78	54.75	50.16
	76	76.86	70.58	65.21	60.15	53.30	48.84
	78	74.87	68.76	63.52	58.60	51.93	47.58
	80	72.99	66.96	61.94	57.12	50.62	46.39

FURNACES OF LOCOMOTIVE BOILERS.

The furnace is that part of the boiler in which the fuel is consumed, the heat generated and partially absorbed, the remaining absorption taking place in the flue-tubes, which convey the products of combustion from the fire, through the water, to the smoke-box.

Since the very general use of coal on railroads has been adopted, and the carrying trade of the country has increased to such an enormous extent, it has become a matter of imperative necessity to obtain a material for the construction of locomotive furnaces that combines the qualities of rapid "steaming," strength, and durability.

The relative merits of iron and copper for the furnaces of locomotive boilers, excepting in certain peculiar cases, are evidently quite as unsettled as any problem in locomotive economy can be. Were it not likely that both are to be superseded by *steel*, the subject would merit a more thorough investigation.

The comparative want of homogeneity in *iron* is both a direct and an indirect cause of its ultimate failure as a material for the furnaces of locomotive boilers. Another disadvantage is its inferior conducting power. This affects the durability of furnace-sheets in proportion to their thickness, as very thick iron plates give way sooner than those that are thinner, because the heat cannot pass

through them rapidly enough to prevent either burning or excessive expansion on the fire side.

The advantages of iron over copper are its superior strength, stiffness, and hardness. Its strength and stiffness allow the use of much thinner and lighter plates than would be safe in case of copper, since the latter metal, however thickly stayed it may be in flat parts, must have considerable thickness for flanging and riveting.

Copper does not materially suffer from oxidation, or any other chemical action to which it is incident in the furnace-sheets. It is also a better conductor than iron. It is more uniform and homogeneous than iron, and will bear a greater degree of irregular expansion and detraction.

Copper is softer, more ductile, and hence more easily worked than iron. It may be stretched to a greater extent in intricate flanging, and may be rolled into one plate of several thicknesses.

The chief disadvantages of copper are its extra dead weight and first cost, and its comparative weakness — its tensile strength being but about 35,800 pounds to the square inch. Copper grows constantly weaker with heat, and at 1100° it is weaker than lead. Its specific gravity is 8.9, while that of iron is 7.7.

The thickness of copper furnace plates is generally $\frac{1}{2}$ inch, while that of iron is $\frac{5}{16}$. The copper is therefore 85 per cent. heavier than iron.

The rates of expansion of iron and copper, under different varieties of temperature, differ very greatly. It has been observed that a locomotive boiler expands $\frac{3}{16}$ of an inch in a length of 15 feet, or, say 1 foot in 1,000, in rising from an ordinary temperature of 62° to 365° — the temperature of steam at 150 pounds pressure per square inch.

According to well-known facts, copper expands by heat half as much again as iron, and taking the mean temperature of the copper of the fire-box at twice as much as the shell, — an assumption which it is supposed is somewhat below the fact, — the vertical expansion of the fire-box would be, upon the whole, three times as much as that of the shell; and the difference of expansion would be twice that of iron, or, at the rate of 1 foot in 500. On a fire-box 5 feet 3 inches high, the difference of expansion would, at this rate, amount to ⅛ of an inch.

The experience of many of our leading roads shows that the average life or wear of an iron fire-box, excepting Lowmoor iron, seldom exceeds "three years," and often fails to reach eighteen months, (the plates in every instance being carefully selected from the standard brands of responsible manufacturers;) many sheets are blistered on account of poor welding, others are "burned out," and in some instances the sheets seem to have hardened, becoming so brittle as to be readily broken with the blow of a hammer.

The internal corrosion of iron for fire boxes seems to be an evil for which neither mechanical science nor

chemistry has as yet suggested a practical remedy; for water merely left under the influence of the atmosphere, in an open vessel, will cause corrosion, and how much more likely is the oxygen of the water to attack the iron when the destructive force of heat is added?

Besides this, water is rarely found pure. Almost every river, spring, and well contains chemical salts, some of them of a very destructive quality.

Sulphur is one of those minerals which experience has shown to have a disastrous effect upon the furnaces of locomotives. There is a great deal of sulphur in some qualities of coal, and the sulphuretted hydrogen gas, disengaged from the fuel, readily attacks and quickly destroys the quality of the metal. Thus we have both external and internal enemies against the durability of the furnace plates.

Steel. — Steel seems to meet the demand for the new material for the furnaces of locomotives, and has been able, under very varying circumstances, within the past seven years, to establish its superiority over iron or copper.

Steel can be used in the construction of furnaces thin enough to transmit the heat rapidly from the fire to the water, and still have sufficient tensile strength to withstand the working pressure, with a surface and fibre of sufficient density to resist the destructive action of foreign substances in the water and fuel, more particularly the sulphur in bituminous coal.

A few years ago the Pennsylvania Railroad Company, under the direction and immediate supervision of Mr. Cassutt, the superintendent of motive power and machinery, inaugurated and successfully continued an elaborate system of experiments upon all the important details connected with railroad motive power.

In the matter of steel plates they embraced a larger amount of experience and information than any other railway company upon this continent.

After a careful test of the best qualities of iron and copper that could be procured in this country or in Europe, they were convinced that, upon their road at least, the durability of either iron or copper was not sufficient to warrant its continued use.

On the contrary, their experiments in the use of steel, at first in fire-boxes only, were in the highest degree successful—so much so, that in the construction of their fire-boxes it is now used entirely, and to a great extent in the general construction of the boiler.

The high degree of tensile strength exhibited by steel plates, ranging from 75,000 to 100,000 pounds to the square inch, allows the use, with safety, of this material thinner than either iron or copper, thus reducing the weight, and rendering the difference in first cost of material an item of less magnitude than is usually supposed.

Then the density and perfect homogeneity of steel

render it nearly impervious to the action of sulphur and other foreign elements in coal, which have proved so destructive to iron and copper, while its ductility and "flanging" qualities are only equalled by the best copper plates.

Another noticeable feature in connection with the use of steel plates for the fire-boxes of locomotives is the utter absence of the soot and cinder ordinarily found clinging to the sides of iron and copper fire-boxes; and as these are, as is well known, non-conductors of heat, they must greatly interfere with the steaming qualities of either of the latter materials.

A great amount of thought and mechanical talent have been devoted to the improvement of the furnaces of coal-burning locomotives within the past ten years, but as yet with only partial success, for though various devices have been introduced for the purpose of rendering the combustion of the fuel more perfect, yet the results obtained have not been sufficiently satisfactory to warrant the adoption of any of them into general use.

The long, shallow fire-box and water-grate, with open stack, seem to be inseparable adjuncts to all locomotives consuming anthracite coal, and this, with a few modifications, may be taken as the rule wherever this class of engines is employed,

But with engines consuming bituminous coal the questions to be considered, in connection with successful combustion, are numerous and important; for while under ordinary circumstances a good quality of bituminous coal may be consumed in an ordinary wood-burning furnace, yet to consume the different classes of this coal, successfully, requires a mechanical construction of fire-box different from that employed in burning wood or anthracite coal.

PROPORTIONS OF FIRE-BOXES, FROM THE BEST MODERN PRACTICE.

Materials. — Best homogeneous cast-steel.

Side and back sheets, $\frac{5}{16}$ inch thick.

Crown-sheets, $\frac{3}{8}$ inch thick.

Flue-sheets, $\frac{1}{2}$ inch thick.

Water space, 3 inches sides and back, 4 inches front.

Stay-bolts, $\frac{7}{8}$ of an inch diameter, screwed and riveted to sheets, $4\frac{1}{2}$ inches from centre to centre.

Crown-bars, made of two pieces of wrought-iron $4\frac{1}{2}$ inches by $\frac{5}{8}$ of an inch, set $4\frac{1}{2}$ inches from centre to centre, and secured by bolts fitted to taper holes in crown-sheets, with head on underside of bolt and nut on top, bearing on crown-bar.

Crown-sheet braced to dome and outside shell.

Fire-door opening formed by flanging and riveting together the outer and inner sheets.

STRENGTH OF STAYED SURFACES IN THE FURNACES OF LOCOMOTIVE BOILERS.

That part of the boiler which forms the sides of the fire-box is necessarily exposed to a vast pressure from the steam which is above it, and some expedient has to be devised to prevent the metal at this part from bulging out.

The two portions of the boiler — that is, the fire-plates forming the sides of the fire-box and the plates forming the external shell of the boiler — are *stayed* together by bolts, that are tapped through from one side to the other, and riveted on each end.

Stay-bolts are placed at a distance of $4\frac{1}{2}$ inches from centre to centre all over the surfaces of the fire-box, and thus the expansion or bulging of one side is prevented by the stiffness or rigidity of the other. Stay-bolts for the fire-boxes of locomotives are generally $\frac{7}{8}$ inch diameter.

Now, in an arrangement of this kind, it becomes necessary to pay considerable attention to the tensile strength of the stay-bolts employed for the above purpose — since the question of the ultimate strength of this part of the boiler is now transferred to them, it being impossible that the boiler plates should give way (except through corrosion) unless the stay-bolts break in the first instance.

Accordingly, all the experiments that have been made by way of test of the strength of stay-bolts, possess the greatest interest for the practical engineer. Mr. Fairbairn's experiments are particularly valuable. He constructed two flat boxes, 22 inches square. The top and bottom plates of one were formed of $\frac{1}{2}$ inch *copper*, and of the other $\frac{3}{8}$ inch *iron*. There was a $2\frac{1}{2}$ inch water space to each, with $\frac{13}{16}$ inch iron stays screwed into the plates and riveted on the ends. In the first box the stays were placed five inches from centre to centre, and the two boxes tested by hydraulic pressure.

In the copper box the sides commenced to bulge out at 450 pounds pressure to the square inch; and at 810 pounds pressure to the square inch the box bursts, by drawing the head of one of the stays through the copper plate.

In the second box the stays were placed at 4 inch centres; the bulging commenced at 515 pounds pressure to the square inch. The pressure was continually augmented up to 1600 pounds. The bulging between the rivets at that pressure was *one-third* of an inch; but still no part of the iron gave way. At 1625 pounds pressure the box burst, and in precisely the same way as in the first experiment,—one of the stays drawing through the iron plate, and stripping the thread *in the plate.*

These experiments prove a number of facts of great value and importance to the locomotive engineer. In the first place, it shows that with regard to iron stay bolts, their tensile strength is at least equal to the grip of the plate.

The grip of the copper bolt is evidently less. As each stay, in the first case, bore the pressure on an area of $5\times5=25$ square inches, and in the second, on an area of $4\times4=16$ square inches, the total strains borne by each stay were, for the first, $815\times25=$ 9 tons on each stay; and for the second, $1625\times16=$ $11\frac{1}{2}$ tons on each stay. These strains were less, however, than the tensile strength of the stays, which would be about 14 tons.

The properly stayed fire-box is the strongest part of a locomotive boiler when kept in good repair.

STAY-BOLTS.

A question here arises in regard to the superiority of iron or copper for stay-bolts; and if it were merely a matter of strength, there could be no doubt that iron is the better material. But it is not a mere matter of strength—it is the durability of the metal that the engineer is most concerned with, and from this point of view there can be no doubt that copper is superior to iron for this purpose.

There are two great evils connected with iron bolts: (1) they crystallize; (2) they corrode. In either case they are likely to snap in halves under any extraordinary pressure—that is, at the very moment when their services are most needed.

Copper has neither of these faults. It has extreme tenacity up to a certain point of its working, and the hot water does not corrode it in the least. Some engineers have tried the effect of placing iron stays in two or three of the upper rows, and copper in the lower rows, where the corrosive influence of the water is more powerful.

But this is opposed to all practical experience, for the upper bolts are always found to break most frequently, from the superior expansion of the inner plate; hence, the material that will endure the most bending should be employed for them.

The total working strength of copper and iron stay-bolts, $\frac{3}{4}$ inch diameter at the base of the thread, screwed and riveted into $\frac{1}{2}$ inch copper plates, taken at $\frac{1}{5}$ of the breaking strain, is, for copper, 3200 pounds, and for iron 4800 pounds. For $\frac{3}{4}$ inch bolts, in $\frac{3}{8}$ inch iron plates, 5600 pounds.

Steel stay-bolts have been occasionally employed in the furnaces of locomotive boilers with good effect. When they have a spring temper they seem to stand the effect of contraction and expansion better than any other material, since their small diameter and great elasticity would permit them to conform to all moderate variations in the boiler caused by ordinary degrees of temperature.

The safe working strength of copper, iron, and steel stay-bolts may be estimated at about $\frac{1}{5}$ of the ultimate strength; but if the screws are cut within the original diameter of the bolt, $\frac{1}{10}$ of the working strength must be deducted.

CROWN-BARS.

The use of crown-bars is to strengthen the crown-sheet of the fire-box; and they should be tested transversely, in order that their stiffness may be fully proved.

It has been found, in practice, that crown-bars $\frac{5}{8}$ of an inch thick, $4\frac{1}{2}$ inches deep, $1\frac{1}{2}$ inches from centre to centre, 3 feet 6 inches long, with their ends resting on the upper edges of the side furnace-sheets, would sustain a load of 15 tons in the centre without permanent set.

TUBES.

There seems to be a great difference of opinion among railway mechanics with reference to the best material for tubes, as copper and brass, which had been extensively employed for wood, seemed to fail under the mechanical action of flying particles of anthracite coal.

The use of tubes is to conduct heat to the surrounding water at the least possible cost — the items of cost being, 1st, waste heat; 2d, maintenance of tubes. Granted, that the best conducting tube is the least durable, and that the poorest conducting tube is the most durable, the question is — by avoiding which species of expense shall the highest economy be attained?

Steel tubes, for coal-burning engines at least, seem to afford better results than any other material now in use, as they can be made lighter, and possess steaming qualities equal, if not superior, to either copper or brass, while the nature of the material affords the requisite degree of surface resistance to the chemical action of the water in the boiler.

Next to steel, for coal-burning engines, iron, undoubtedly, gives the best results. The great difficulty heretofore experienced in setting them, and afterwards keeping them tight, is now permanently obviated by what is known as the "safe end"—a copper thimble placed on the end of the flue, in such manner that when the flue is expanded the copper readily adapts itself to the surface of the flue, and thus forms a packing, or set, in the flue-sheets.

Wearing of Tubes.—Wearing generally occurs at the fire-box end; the flange by which the tube is set is often burned or cut through.

Resistance of Tubes.—The resistance of tubes is manifestly due entirely to their hardness; the materials then range in the following order—steel, iron, brass, copper.

Burning of Tubes.—The burning of tubes is entirely due to a contracted water space, bad circulation between them, and the deposit of scale adhering to the outer surface caused by impurities in the water.

When brass and copper tubes become over-heated, the elongation of the metal causes them to buckle and sag, and as a result, the water-space being very much diminished, and the tubes perhaps touching each other, they are soon burned out.

Breaking of Tubes.—The breaking of tubes generally occurs close to the fire-box tube-shell and the shell of the boiler. Copper will stand this action better than the harder materials, but it has more to stand by reason of its larger limit of expansion.

Steel Tubes.—Steel tubes, however, possess all the good qualities of copper, due to homogeneousness, without its great limit of expansion, in addition to the strength of iron.

Sagging of Tubes.—The sagging of tubes is dependent on the softness of the metal and on the length and diameter of the tube and its consequent stiffness.

Leakage of Tubes.—The leakage of tubes is the result of defective setting, unequal expansion or overheating.

Corrosion of Tubes.—Copper and brass are quite superior to iron, resisting both the action of the water and the sulphur in coal. Steel approaches the excellence of copper in both these particulars.

Length and Diameter of Tubes.—Tubes 2 inches in diameter and 11 feet long, placed in vertical rows ¾ of an inch apart, give most satisfactory results, as such an arrangement admits of an easy circulation of the water and free escape of steam from the heating surface to the steam dome, besides giving ready access to the mud in its passage from the water to the bottom of the boiler.

TABLE

OF SUPERFICIAL AREAS OF EXTERNAL SURFACES OF TUBES OF VARIOUS LENGTHS AND DIAMETERS IN SQUARE FEET.

These tables are designed to facilitate the calculation of the heating surface of the tubes in tubular boilers, and are adapted for tubes of various lengths, from 8 to 13 feet, advancing by inches, and of various diameters, from $1\frac{5}{8}$ to $2\frac{1}{4}$ inches, advancing by $\frac{1}{8}$ of an inch.

Explanation. — The large figures at the end of the horizontal lines give the length of tubes in feet, and the small intermediate figures on the same line give the additional inches. The vertical column on the left gives the diameters of the tubes in inches. The numbers in the tables represent the superficial area of our tube in square feet, and decimal parts thereof, for the different lengths and diameters of tubes required.

Example. — Required, the heating surface of 163 tubes, $1\frac{3}{4}$ inches diameter and 11 feet 10 inches long. Thus, having found the length (11 feet 10 inches) in the above-named horizontal line of figures, trace downwards to the line opposite the diameter ($1\frac{3}{4}$) in the vertical column on the left, where will be found the number 5.421, being the area of the tube, and which, being multiplied by the number of tubes (163), gives the total area of 883,623 square feet, thus reducing the whole process to a simple matter of multiplication.

SUPERFICIAL AREAS OF EXTERNAL SURFACES OF TUBES OF VARIOUS LENGTHS AND DIAMETERS IN SQUARE FEET.

DIAM. OF TUBE. Inches.	8 FEET.	1 INCHES.	2	3	4	5	6	7	8	9	10	11
$1\frac{5}{8}$	3.403	3.438	3.474	3.509	3.545	3.580	3.616	3.651	3.686	3.722	3.757	3.793
$1\frac{3}{4}$	3.665	3.703	3.741	3.779	3.817	3.856	3.894	3.932	3.970	4.008	4.046	4.085
$1\frac{7}{8}$	3.926	3.967	4.008	4.049	4.090	4.131	4.172	4.213	4.254	4.295	4.335	4.376
2	4.188	4.232	4.276	4.319	4.363	4.406	4.450	4.494	4.537	4.581	4.624	4.668
$2\frac{1}{8}$	4.450	4.496	4.543	4.589	4.636	4.682	4.728	4.775	4.821	4.867	4.914	4.960
$2\frac{1}{4}$	4.712	4.761	4.810	4.859	4.908	4.957	5.006	5.055	5.105	5.154	5.203	5.252

Inches.	9 ft.	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
$1\frac{5}{8}$	3.828	3.864	3.899	3.935	3.970	4.006	4.041	4.076	4.112	4.147	4.183	4.218
$1\frac{3}{4}$	4.123	4.161	4.199	4.237	4.276	4.314	4.352	4.390	4.428	4.466	4.505	4.543
$1\frac{7}{8}$	4.417	4.458	4.499	4.540	4.581	4.622	4.663	4.704	4.745	4.785	4.826	4.867
2	4.712	4.756	4.799	4.843	4.886	4.930	4.974	5.017	5.061	5.104	5.148	5.192
$2\frac{1}{8}$	5.006	5.053	5.099	5.145	5.192	5.238	5.285	5.331	5.377	5.424	5.470	5.516
$2\frac{1}{4}$	5.301	5.350	5.399	5.448	5.497	5.546	5.595	5.645	5.694	5.743	5.792	5.841

SUPERFICIAL AREAS OF EXTERNAL SURFACES OF TUBES OF VARIOUS LENGTHS AND DIAMETERS IN SQUARE FEET.

DIAM. OF TUBE.	FEET.	INCHES.										
Inches.	10	1	2	3	4	5	6	7	8	9	10	11
1⅝	4.254	4.289	4.325	4.360	4.396	4.431	4.466	4.502	4.537	4.573	4.608	4.644
1¾	4.581	4.619	4.657	4.696	4.734	4.772	4.810	4.848	4.886	4.924	4.963	5.001
1⅞	4.908	4.949	4.990	5.031	5.072	5.113	5.154	5.195	5.235	5.276	5.317	5.358
2	5.236	5.279	5.323	5.366	5.410	5.454	5.497	5.541	5.584	5.628	5.672	5.715
2⅛	5.563	5.609	5.655	5.702	5.748	5.795	5.841	5.887	5.934	5.980	6.026	6.073
2¼	5.890	5.939	5.988	6.037	6.086	6.135	6.184	6.234	6.283	6.332	6.381	6.430
Inches.	11 ft.	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
1⅝	4 679	4.715	4.750	4.785	4.821	4.856	4.892	4.927	4.963	4.998	5.034	5.069
1¾	5.039	5.077	5.115	5.154	5.192	5.230	5.268	5.306	5.345	5.383	5.421	5.459
1⅞	5.399	5.440	5.481	5.522	5.563	5.604	5.644	5.685	5.726	5.767	5.808	5.849
2	5.759	5.803	5.846	5.890	5.934	5.977	6.021	6.064	6.108	6.152	6.195	6.239
2⅛	6.119	6.165	6.212	6.258	6.304	6.351	6.397	6.444	6.490	6.536	6.583	6.629
2¼	6.479	6.528	6.577	6.626	6.675	6.724	6.774	6.823	6.872	6.921	6.970	7.019

SUPERFICIAL AREAS OF EXTERNAL SURFACES OF TUBES OF VARIOUS LENGTHS AND DIAMETERS IN SQUARE FEET.

DIAM. OF TUBE.	FEET.	INCHES.										
Inches.	12	1	2	3	4	5	6	7	8	9	10	11
1⅝	5.105	5.140	5.175	5.211	5.246	5.282	5.317	5.353	5.388	5.424	5.459	5.494
1¾	5.497	5.535	5.574	5.612	5.650	5.688	5.726	5.764	5.803	5.841	5.879	5.917
1⅞	5.890	5.931	5.972	6.013	6.054	6.094	6.135	6.176	6.217	6.258	6.299	6.340
2	6.283	6.326	6.370	6.414	6.457	6.501	6.544	6.588	6.632	6.675	6.719	6.762
2⅛	6.675	6.722	6.768	6.814	6.861	6.907	6.954	7.000	7.046	7.093	7.139	7.185
2¼	7.068	7.117	7.166	7.215	7.264	7.314	7.363	7.412	7.461	7.510	7.559	7.608
Inches.	13 ft.	1 in.	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
1⅝	5.530	5.565	5.601	5.636	5.672	5.707	5.743	5.778	5.814	5.849	5.884	5.920
1¾	5.955	5.994	6.032	6.070	6.108	6.146	6.184	6.223	6.261	6.299	6.337	6.375
1⅞	6.381	6.422	6.463	6.504	6.544	6.585	6.626	6.667	6.708	6.749	6.790	6.831
2	6.806	6.850	6.894	6.937	6.981	7.024	7.068	7.112	7.155	7.199	7.242	7.286
2⅛	7.232	7.278	7.324	7.371	7.417	7.463	7.510	7.556	7.603	7.649	7.695	7.742
2¼	7.657	7.706	7.755	7.804	7.853	7.903	7.952	8.001	8.050	8.099	8.148	8.197

COMBUSTION OF FUEL IN LOCOMOTIVE FURNACES.

In the locomotive furnace the main loss is sustained by the immense velocity in gases when the engine is under heavy strain. A nozzle that will give, under ordinary strain of engine, very satisfactory results, will, under a heavy strain, tear out the fire, or reduce the temperature in gases to a degree where ignition is impossible. This velocity might, to some extent, be reduced by giving a larger grate-surface; but in locomotives this cannot be done beyond a certain limit, without inconvenience and loss in other parts of the machinery.

A locomotive under 9,600 pounds strain — even if the influx of the air was well regulated — would still have a velocity in gases equal to 72 feet per second, or that of a storm. This is mainly owing to the small available grate-surface, which forces the current to accept a high velocity to fill the vacuum made in a given time.

This may be in part avoided by hollow stay-bolts but, while their use is beneficial for the above-mentioned purposes, they are productive of an evil almost as bad — that of receiving at times too much oxygen.

Different devices have been resorted to, such as brick arches, water-tables, and deflectors, for the purpose of creating a recoil of the currents and increasing the friction, which may react on the grate-sur-

face, thereby lessening the influx of air, and keeping the gases in contact with the fire for a longer period, in order to render the combustion of the fuel more perfect.

But even these means are but imperfect, since the current is never constant, and the square surface of the nozzle always so, which must create imperfections. The only radical mode of obviating these deficiencies, therefore, seems to be to regulate the influx of air according to requirements, which may be effected by the exercise of care and good judgment.

Light passenger engines always consume the fuel to a better advantage than the heavy freight engines, because their grate-surface is better proportioned to the work done, and in a light strain the proportion between the steam expelled and the air inhaled is nearer the correct one. Besides, there being no large quantity of air inhaled, there cannot be a very great velocity in the current; consequently, the contact between the oxygen and the luminous gases is continued through the time necessary for complete combustion.

It is well known that the air entering through the grate is twice, and in many cases three times, greater than the weight of the discharged steam, while the proportions between the steam discharged and the air inhaled ought in all cases to be about the same. The following rules, if carried out, would give most satisfactory results:

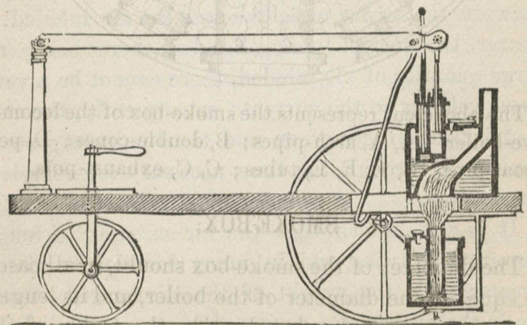
First.—The difference in pounds between the steam exhausted and the air inhaled ought to be, in all cases, about the same.

Second.—The bulk of fuel on the grate should always be in proportion to the fuel consumed.

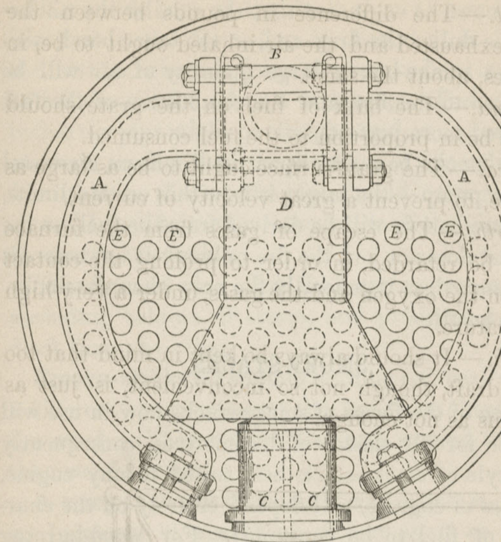
Third.—The grate-surface ought to be as large as possible, to prevent a great velocity of current.

Fourth.—The escape of gases from the furnace should be retarded, in order to prolong the contact between the oxygen and the gases, under a very high temperature.

Fifth.—It should always be kept in mind that too much draft, though not so inconvenient, is just as injurious as not enough.



MURDOCK'S LOCOMOTIVE—1784.



The above cut represents the smoke-box of the locomotive-boiler. A, A, arch-pipes; B, double-cones; D, petticoat-pipe; E, E, E, E, tubes; C, C, exhaust-pots.

SMOKE-BOX.

The diameter of the smoke-box should, in all cases, be equal to the diameter of the boiler, and its length, from the face of the flue-sheet to the inside of the front door, about 1¼ times the length of the stroke of the engine, as the size of the smoke-box has much to do with the perfect combustion of the fuel. It is well known to engineers that the smaller the smoke-box the duller the fire; and, on the other hand, with a large smoke-box a large quantity of air will be admitted to the fire, and the combustion of the fuel rendered more perfect.

The smoke-box acts upon the fire as an air-vessel upon a pump—the larger it is, within certain limits, the more benefit will be derived from the fuel, as the exhaust does not jerk the fire or carry it out before it is consumed, as is generally the case when the smoke box is small.

SMOKE-STACKS.

None of the forms of smoke-stacks now in use will answer for all classes of locomotives, consequently the style of smoke-stack best suited to any engine, or class of engines, will depend entirely on the character of fuel to be consumed. For wood-burning engines the "bonnet" stack, having a diameter of from 5 to 5½ feet at the top, gives the most satisfactory results, as this form of stack insures a better draft, other things being equal, than any other pattern now in use. There may be other stacks that more effectually prevent the emission of sparks, but it is accomplished at the expense of the draft.

A large diameter at the height of the cone, and a large area of wire-netting, are necessary to insure good draft and prevent sparks being ejected in objectionable quantities.

The inside pipe of the stack should be as high as practicable, and from 4 to 4½ diameters in length; the bottom, where it joins the smoke-box, ought to be bell-mouthed for 5 or 6 inches up. The next 18 inches the pipe might be straight, and, as a rule, about one inch smaller than the diameter of the cylinders; from that to the top the pipe should enlarge at the rate of 1 inch to the foot, the inside of the pipe to be as smooth as possible.

This form of pipe offers the least resistance to the ascending column of steam, and produces a better draft than any other.

Smoke-stacks for engines burning soft coal require a different construction at the top from those burning wood, as they require less area around the cone than wood-burners.

A stack that will clean itself well—that is, permit no lodgment of sparks or cinders in it or in the smoke-box — and at the same time throw no fire or large cinders, and has a good draft, will answer best for burning soft coal.

The particular form for the top of the stack is not very material, yet that known as the diamond-shape top, with an annular space between the outer edges of the cone and wire netting of from 3 to 4 inches, gives very satisfactory results, as by this arrangement the gumming of the netting is avoided.

For engines burning anthracite coal, the plain open stack, without cone or netting, gives the best satisfaction.

EXHAUST-NOZZLE.

Double exhaust-nozzles are in all cases preferable to single, on account of the back pressure produced by the single nozzle in the opposite cylinder at the moment and during the continuance of the exhaust.

The top of the exhaust-nozzles should be as high as the third or fourth row of tubes from the bottom, and they should be as close as possible, and so directed that the exhaust steam will strike the centre of the cone at the top of the stack.

Petticoat- or Clearance-pipe. — The petticoat-pipe, in good practice, is generally about $\frac{2}{3}$ the diameter of the inside pipe of the stack, and to give satisfactory results, the top of the pipe ought to be about three inches below the top of the smoke-box, and the bottom the same height, or even with the top of the exhaust-nozzles.

Grate-bars. — For wood- and soft coal-burning locomotives the old ordinary grate, with about $\frac{1}{2}$ inch opening, gives very satisfactory results. For anthracite coal-burners the water-grate or water-tubes are extensively used, and seem to answer a very good purpose.

Ash-pans. — The ash-pans for wood- and coal-burning engines should be as nearly air-tight as possible when the dampers are closed.

For wood-burning engines the depth from the bottom of the grates to the ash-pan ought to be about 9 inches; for soft coal-burners, not less than 10 inches; and for anthracite coal-burners 12 to 13, or even 14 inches.

Dampers should be used front and back, and when shut, stand at an angle of about 35° from perpendicular; the bottom of the ash-pan should be rounded up or raised about two inches at each end.

Side doors are very convenient on coal-burners for cleaning the pans out.

SAFETY-VALVES.

The form and construction of this indispensable adjunct to the steam-boiler are of the highest importance, not only for the preservation of life and property, which would, in the absence of this means of safety, be constantly jeopardized, but also to secure the boiler from undue strains and ultimate destruction.

Increasing the pressure to a dangerous degree, in a steam-boiler, would be impossible if the safety-valve were what it is supposed to be — a perfect means for liberating all the steam which a boiler may produce with the fires in full blast, and all other means for the escape of steam closed. Until such a safety-valve shall be devised and adopted into general use, safety from gradually increasing pressure must depend, to a certain extent, on the watchfulness of the engineer.

It is supposed that a gradually increasing pressure can never take place if the safety-valve is in good working order, and if it have proper proportions. Upon this assumption, universally acquiesced in, when there is no accountable cause, explosions are attributed to the "sticking" of the valves, or to "bent valve-stems," or "inoperative" valve-springs. As the safety-valve is the sole reliance in case of neglect or inattention on the part of the engineer, it is important to examine its mode of working closely.

The safety-valve is designed on the assumption that it will rise from its seat under the statical pressure in the boiler, when this pressure exceeds the exterior pressure on the valve, and that it will remain off its seat sufficiently far to permit all the steam which the boiler can produce to escape around the edges of the valve.

The ordinary safety-valve, as at present constructed, consists of a disc, which closes the outlet of a short pipe leading from the boiler. The area of the disc, or diameter of the valve, is usually determined from theoretical considerations, based on the velocity of the flow, or upon the results of experiments made to ascertain the area of orifice necessary for the flow of all steam a boiler can produce under a given pressure. The fact is recognized by engineers and constructors that the real diameters of safety-valves must be greater than the theoretical orifices, because common observation shows that the valves do not rise

appreciably from their seats; and to make the outlet around the edges of the valve equal in area to the pipe, the valve should rise in all cases $\frac{1}{4}$ its diameter.

Every locomotive boiler should have two safety-valves, held in place by springs of sufficient elasticity to permit a lift of valve from its seat to give the required area of opening for the escape of all the steam such boiler will make without a greater increase of pressure per square inch than five pounds over that at which the valve commences to rise.

With the lift of one-sixteenth of an inch, at a pressure of 130 pounds per square inch, two three-inch valves would permit the escape of 12 cubic feet of steam per second, or nearly double the quantity that a boiler having 900 square feet of heating surface will supply.

The springs connecting the safety-valves from levers with the boiler should be of sufficient length to permit a lift of the valves from their seats of at least $\frac{1}{16}$ of an inch with no greater addition of pressure than five pounds per square inch above the maximum pressure.

The valve-seats of safety-valves should in all cases be made of brass, and the bearing or mitre on the valve face should not exceed $\frac{1}{8}$ of an inch.

Every engineer should know that the safety-valves on his boiler are at all times in good working order, and any engineer that would screw or weigh down his safety-valves for the purpose of increasing the pressure beyond that which he had reason to believe was safe, ought to be disqualified from ever taking charge of an engine again.

TABLE

SHOWING THE RISE OF THE SAFETY-VALVES, UNDER THE INFLUENCE OF DIFFERENT PRESSURES. "THE RISE OF THE VALVES IN PARTS OF AN INCH."

12 lbs.	20 lbs.	35 lbs.	45 lbs.	50 lbs.
$\frac{1}{36}$ inch.	$\frac{1}{48}$ inch.	$\frac{1}{54}$ inch.	$\frac{1}{65}$ inch.	$\frac{1}{86}$ inch.

60 lbs.	70 lbs.	80 lbs.	90 lbs.
$\frac{1}{86}$ inch.	$\frac{1}{132}$ inch.	$\frac{1}{168}$ inch.	$\frac{1}{168}$ inch.

Or, taking average values, the rise for pressures from 10 to 40 pounds is $\frac{1}{40}$ of an inch; from 40 to 70 pounds $\frac{1}{80}$, and from 70 to 90 pounds, $\frac{1}{120}$ of an inch.

These results show that the rise diminishes rapidly as the pressure increases—a result which is indicated by theory. The very small rise for pressure from 70 to 90 pounds, $\frac{1}{120}$ of an inch, is remarkable.

Safety-valves are only a means of *safety* when well constructed and well cared for.

Tests of safety-valves are very much needed, and should receive special attention from master mechanics, engineers, and steam users in general; but tests, to be of any value, must be practical, and should be done by subjecting them to actual use on steam-boilers that were doing regular duty.

STEAM-GAUGES.

It is generally admitted that boiler explosions take place from different causes, and prominent among these causes are weakness, faulty construction, and over-pressure. It is to provide against the latter contingency that a *good gauge* is a real necessity wherever steam is employed; but it is also a well-known fact that about one-half the gauges in use are either notoriously unreliable or completely worthless.

Imperfectly graduated in the first place, and liable to become still further out of the way after a little use, many of them are really sources of danger instead of safety; for their erroneous indications create a feeling of safety which sets the vigilance of the engineer to sleep. Even gauges bearing the most satisfactory test, when new, are oftentimes found to be utterly unreliable when placed upon boilers and subjected to the conditions to which all gauges are subjected when in use.

Steam-gauges, like safety-valves, are only a means of *safety* when properly constructed, accurately graduated, and well cared for.

A great many worthless *steam-gauges* are palmed off on steam users, the only proof of their efficiency being that they worked well under some experimental test; but when subjected to the conditions of constant use, they have proved utterly worthless. Practical tests of *steam-gauges* are very much needed.

INSTRUCTIONS FOR THE CARE AND MANAGEMENT OF LOCOMOTIVE BOILERS.

After heavy rains the water should be frequently run out of the boiler, in order to prevent the deposit of sediment on the sheets and flues.

The deposits of scale and earthy matter should be removed from the crown-sheet as often as possible, in order to prevent the crown-sheet from being burnt or sprung.

Every locomotive boiler should be provided with mud plugs on the sides of the shell on a level with the crown-sheet, for the purpose of washing out the mud with a hose from between the crown-bars. This could be done without weakening the boiler by riveting an extra piece on the inside of the shell in the line of the holes.

The accumulations of mud should be removed from the water-legs of the furnace and the barrel of the boiler as often as convenient, and the spaces thoroughly washed out with a hose.

Boilers should never be blown out while hot, as the plates, flues, and braces retain sufficient heat to bake the deposits of mud into a hard scale, that becomes firmly attached to their surface.

The boiler should always be allowed to stand for several hours, or until it is cold, before the water is run out; the deposit of mud and scale will then be

found to be quite soft, and can be easily washed out with a hose from all accessible places.

There seems to be an impression in the minds of some engineers that blowing out a boiler under pressure has a tendency to remove the deposits of mud from the boiler, but experience has shown this to be a very grave mistake, as already shown.

Boilers should never be filled with cold water while hot, as it has a very injurious effect, causing severe contraction of the seams and stays, which very often induces fracture of stays or leakage in the seams and tubes.

Many boilers, well constructed and of good material, have been ruined by being blown out under a high pressure of steam, and then suddenly filled with cold water.

Fractures, strained joints, and leaky tubes are generally attributed to poor workmanship and poor material, when the mischief generally arises from the boiler being blown out under high steam, or filled with cold water while hot.

The tubes of boilers being generally of thinner material than the shell, consequently cool and contract sooner; for this reason the boiler should never be filled with cold water while the tubes are hot.

If it is expected that the boiler will last to a good *old age*, and render faithful service, it must be well cared for.

FIREMEN ON LOCOMOTIVES.

The general custom on nearly all the principal railroads in this country is to promote their firemen to the position of engineers, as it has been found, by experience, that locomotive engineers promoted from firemen were more reliable than machinists taken from the shops, unless the machinist has had sufficient experience as a fireman to make him well acquainted with the duties of engineers; and with this object in view, particular attention is paid to the selection of young men for firemen, and none but smart, active young men of good moral character and perfectly sober habits will receive any encouragement.

After firing for about three years, if they give evidence of sufficient capacity and carefulness, they are generally placed in the repair shop or round-house for one year, to enable them to learn the use of tools, but more particularly to make them acquainted and familiar with the construction of the locomotive engine and the manner of taking its machinery apart and putting it together again.

If, at the end of the candidate's fourth year, he has conducted himself properly, and given sufficient evidence of his knowledge of the construction of a locomotive engine and its management to make a good engineer, he is promoted to a *third-class* engineer, with pay of twenty dollars per month less than that of a *first-class* engineer; but if not found capable, he is dropped.

After one year's trial as third-class, if he still gives evidence of capacity and carefulness, he is advanced one grade higher, or to the position of second-class, with pay of ten dollars per month less than a first-class engineer.

If, after the expiration of one year as a second-class engineer, he is qualified in every way for a first-class engineer, he is advanced to that grade with first-class pay; but if not found competent in every particular, he is considered out of the regular order of promotion.

In view of the above facts, it is perfectly obvious that every fireman who aspires to the position of a locomotive engineer ought to inform himself, as far as possible, on all questions connected with the care and management of the locomotive engine and boiler. He should improve every opportunity, make good use of leisure hours, connect himself with some public library, read scientific books, especially those treating on subjects connected with his trade or calling, and endeavor to gain all possible information on all subjects connected with his business from the most reliable and practical sources.

He should ask questions relating to his business of persons that he has reason to believe are competent to inform him, as he can do so without any sacrifice of feeling, being aware that he is not expected to know much about the duties of his calling at this stage of his apprenticeship.

He must remember that if the profession or calling of the locomotive engineer is to be dignified, the men that follow it for a trade must also be elevated — that it is not the work which gives dignity to the man, it is the character of the man that gives dignity to the vocation he pursues; that it is only when one class of mechanics becomes equal to another in respect to intelligence, culture, and refinement, that their calling becomes equally dignified; and, also, that the cultivation of the mind is the first step towards eminence in any trade or profession.

He must understand that men's labor is like merchandise,—the price is regulated, to a certain extent, by the demand, and if there are different qualities of the same article in the market, and purchasers are expected to pay as much for the inferior article as for the good one, they will very naturally take the best.

Every fireman who goes on a locomotive with the intention of becoming an engineer should do so with the determination of making himself, if possible, a first-class engineer. But we know that it is not possible for all to do this, as there is among firemen, as in all other trades and professions, a great many men who are totally unfit for the business-- men that perhaps would succeed, to a certain extent, in some other pursuit, but who become a failure, and often a reproach on the profession they have adopted, simply for the reason that they made a mistake in the selection of a suitable trade.

No fireman should make up his mind to become an engineer unless satisfied that he possesses the following natural qualifications:

1. The power of long continued and unwearied attention, that he may be able to watch the road and his engine without the slightest relaxation, during the longest possible trip.

2. Endurance, both of body and mind, which in case of accidents and delays is often tested to the utmost. No man easily worn out has any business with running a locomotive.

3. Sharpness of sight, power of distinguishing colors of signals, soundness of hearing, and generally that perfection of the senses which enables one to observe accurately objects at a distance.

4. Energy, decision, and presence of mind, the absence of which in a runner will probably cause him to lose a train, or a life, or many lives in the course of his service.

5. Akin to the above is alertness of mind, which makes men alive to the slightest occurrences within reach of their senses, and is often strikingly developed in hunters and men having charge of sentries and outposts in time of war. All the senses can be cultivated, *sight* excepted.

FIRING.

In estimating the relative merits of different locomotives, it is always assumed that the fuel is burned under conditions with which the men who supply coal to the furnaces have nothing whatever to do — in short, that any man who can throw coals on a fire and keep his bars clean must be as good as any other man who can do, apparently, the same thing. But this conclusion is totally erroneous, as it is within the experience of every engineer that many engines now in operation throughout the country consume from two to three times as much fuel, per horse-power, as is required in those that are more perfectly constructed and economically managed.

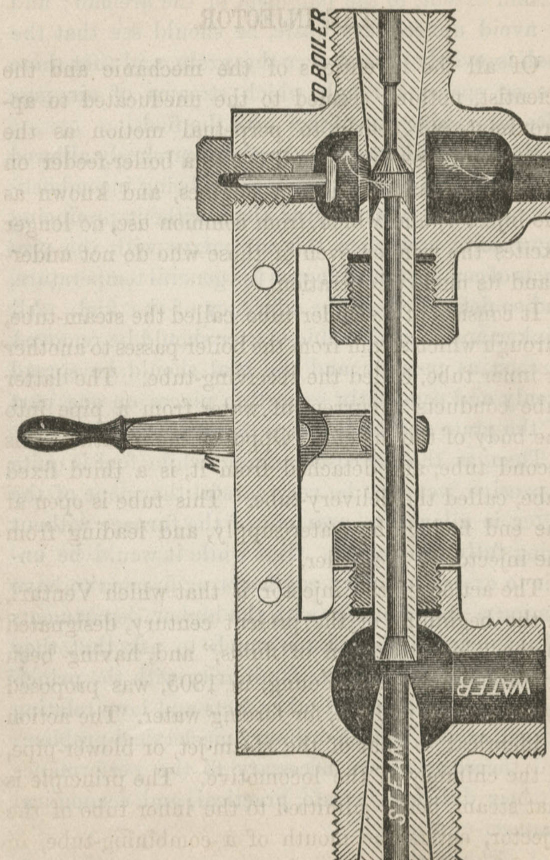
In every case, a large proportion of this waste occurs in the furnace; and while some of it is unavoidable, much of it is due to bad firing, and this bad firing is as often due to the want of knowledge as to carelessness and inattention.

When the coal is in large lumps, so that the spaces between them are of considerable size, the depth may be greater than where the coal is small and lies compactly; and where the draft is very strong, so that the air passes with great velocity over or through the fuel, there is not time for the carbonic acid to combine with and carry off the coal, and consequently a bed of greater depth may with propriety be used. Of course the depth in all cases must depend, to a

certain extent, to the judgment of the fireman; and to avoid unnecessary waste, he should see that the coal is evenly spread over the grate, and that there are no spaces through which streams of air pass without coming in contact with the fuel.

Masses of clinkers are sometimes carelessly allowed to accumulate on the grate; these, being incombustible, allow air to pass over them without producing any result; and when this air mixes with the products of combustion, it lowers the general temperature, and so detracts from the efficiency of the fuel. All clinker and incombustible matter should be removed as soon as possible, and the coal should be spread evenly and compactly — no thin places on one part of the grate and large heaps on another.

Then, as the air costs nothing, while fuel is quite expensive, we must be very careful that none of the latter is allowed to pass out of the furnace without being fully neutralized. But while it would be unfair to expect ordinary engineers or firemen to have a minute acquaintance with the higher departments of chemistry, it is not too much to ask that they should have a moderate familiarity with the principles of combustion, and other facts and laws relating to heat, as well as such ordinary mechanical problems and theorems as are necessary to the performance of their duties in a safe, practical, and economical manner.



RUE'S "LITTLE GIANT" INJECTOR.

THE INJECTOR.

Of all the inventions of the mechanic and the scientist, nothing seemed to the uneducated to approximate so nearly to perpetual motion as the instrument now in general use as a boiler-feeder on locomotives and stationary engines, and known as the injector, and which, from common use, no longer excites the wonder even of those who do not understand its mode of operation.

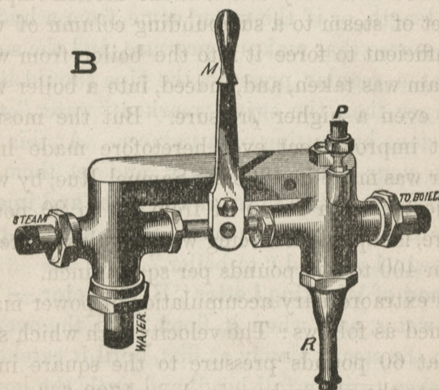
It consists of a slender tube, called the steam-tube, through which steam from the boiler passes to another or inner tube, called the receiving-tube. The latter tube conducts a current of water from a pipe into the body of the injector. Opposite the mouth of this second tube, and detached from it, is a third fixed tube, called the delivery-tube. This tube is open at the end facing the water-supply, and leading from the injector to the boiler.

The action of the injector is that which Venturi, in the beginning of the present century, designated as the "lateral action of fluids," and, having been investigated by Dr. Young, in 1805, was proposed by Nicholson, in 1806, for forcing water. The action is identical to that of the steam-jet, or blower-pipe, in the chimney of the locomotive. The principle is that steam, being admitted to the inner tube of the injector, enters the mouth of a combining-tube, in the form of a jet, near the top of the inlet water-pipe. If the level of the water be below the injector, the escaping jet of steam, by its superficial action (or friction) upon the air around it, forms a partial vacuum in the combining-tube and inlet-pipe, and the water then rises in virtue of the external pressure of the atmosphere. Once risen to the jet, the water is acted upon by the steam in the same manner as the air had been seized and acted upon in first forming the partial vacuum into which the water rose.

Giffard's discovery was that the motion imparted by a jet of steam to a surrounding column of water was sufficient to force it into the boiler from which the steam was taken, and, indeed, into a boiler working at even a higher pressure. But the most important improvement ever heretofore made in the injector was made in 1868, by Samuel Rue, by which the injector, with steam of from 80 to 90 pounds' pressure, is capable of forcing water against a pressure of from 400 to 450 pounds per square inch.

This extraordinary accumulation of power may be explained as follows: The velocity with which steam —say at 60 pounds' pressure to the square inch—flows into the atmosphere is about 1700 feet per second. Now suppose that steam is issuing, with the full velocity due to the pressure in the boiler, through a pipe an inch in area, the steam is condensed into water, at the nozzle of the injector, without suffering any change in its velocity. From this cause its bulk will be reduced, say 1,000, and, therefore, its area

of cross-section — the velocity being constant — will experience a similar reduction. It will then be able to enter the boiler again by an orifice $\frac{1}{1000}$th part of that by which it escaped. Now it will be seen that the total force expended by the steam through the pipe, on the area of an inch, in expelling the steam jet, was concentrated upon the area $\frac{1}{1000}$th of an inch, and, therefore, was greatly superior to the opposing pressure exerted upon the diminished area.



RUE'S "LITTLE GIANT" LETTER "B" INJECTOR.

How to put on Letter "B" Injector.—Put the injector in a horizontal position above the foot-board, and within easy reach of the engineer, using as short a length of pipe for "steam" and "deliverance to the boiler" as possible. Put an ordinary globe or angle-valve on the steam supply-pipe, for starting, etc., taking the steam from the highest part of the boiler, and attaching it to the swivel marked "steam." Attach the water supply-pipe to the swivel marked "water," putting an ordinary water-cock on the supply-pipe near to the injector. A good supply of water must be had, and if taken from a tank, give it a good fall. The mouth of the pipe should be enlarged, and a screen with small meshes placed over it to keep out dirt; if the supply-pipe be over ten feet in length, or if the water come from a hydrant, or any source that makes a pressure, and the supply is not at a regular pressure, the pipe should be one size larger than the swivel marked "water," which can be done by putting on a reducer. At this point turn on your steam and water, and let them flow through the injector, to see if the pipes and injectors are free from dirt. Then attach the "delivery-pipe" to the swivel marked "to boiler."

Method of Working Letter "B" Injector.—Turn on the water, and, when it flows from the overflow, turn on the steam, slowly at first, until it catches the water, then turn on full head, and push the lever M slowly either forwards or backwards, as seems requisite, until neither steam nor water shows at the overflow. Failure to work will always show at the overflow, and when the point is ascertained at which the lever is to be set for the steam pressure to be carried, it can be regulated, and then left to stand at that position when the steam and water are shut off. The lever is only used to regulate the proportionate amounts of water and steam.

But when water is to be lifted by this injector, a small steam-pipe leading from the boiler and furnished with a valve that opens with a quick motion, is attached to the swivel "P," by means of which a steam-jet is thrown into the tube "R," and the water lifted. But at this point it is necessary to examine the tube in order to ascertain if the suction is good, or if it lifts the water readily, and if so, the steam supply-pipe can be attached to the swivel marked "steam," and the injector cleared of any dirt that may have collected in the boiler; then the delivery-pipe to the boiler may be attached to the swivel marked "to boiler." Great care should be taken to see that the supply-pipe through which the water is lifted is perfectly air-tight, as any leak in the pipe will interfere with the working of the injector. Washers should never be used in the swivels connecting the pipes to the injector, as the joints are all ground.

The performances of this little machine are actually astonishing, as, with a steam pressure of 80 or 90 pounds per square inch on the boiler to which it is attached, it will successfully force water into other boilers under a pressure of from 400 to 450 pounds per square inch. It can be regulated to supply any required quantity of water, and is equally reliable when it is used every day or not more than once a year.

Hints to Locomotive Engineers.—The "Little Giant" injector can be set to feed a steady stream, but in some cases it may be advisable to set it so that the boiler will lose a small quantity of water in running between stations; then, by keeping the injector at work while the engine is standing at the station, a good supply of water will be obtained to run to the next station. This plan, properly carried out, will make a great saving in fuel, and also have a tendency to prevent boiler explosions, as, when the engine is stopped, the whole heat of the fire is thrown against the sides of the furnace and the crown-sheet, which, if the circulation of the water is not kept up, will soon become overheated, and may possibly cause an explosion.

The injector, as a boiler-feeder, possesses advantages in point of economy over all other devices, as the steam that is admitted to the injector, from the boiler, returns to the boiler, carrying with it more than twenty times its weight of water. Not a drop of water is lost, nor a particle of steam wasted. It occupies but little space, requires no oil, packing, or any special care, and very little, if any, repairs. It can be set up in almost any position; but, where circumstances will permit, a *horizontal* position is very much to be preferred. On locomotives, it should invariably be placed above the foot-board, and within easy reach of the engineer.

There should be one of these injectors attached

to every locomotive, as they are always available and reliable in case of stoppage, accident, or detention from any cause whatever. Therefore every engineer should encourage their introduction on locomotives, steamships, stationary and portable steam-boilers.

TABLE OF CAPACITIES

OF

RUE'S "LITTLE GIANT" INJECTOR.

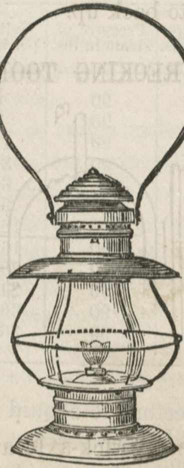
Size of Injectors.	Size of Pipe Connections.	Pressure of steam in lbs.	Gallons per hour.	Nominal Horse-Power.
0	$\frac{1}{4}$	90	60	4 to 8
1	$\frac{3}{8}$	90	90	6 " 12
2	$\frac{1}{2}$	90	120	8 " 20
3	$\frac{3}{4}$	90	300	20 " 40
4	1	90	600	40 " 80
5	$1\frac{1}{4}$	90	900	60 " 120
6	$1\frac{1}{4}$	90	1200	80 " 160
7	$1\frac{1}{2}$	90	1620	140 " 225
8	2	90	2040	200 " 275
9	2	90	2480	250 " 350
10	2	90	3000	300 " 400
12	$2\frac{1}{2}$	90	3600	350 " 500

In ordering injectors, it should be always stated whether the connecting-pipes are copper, brass, or iron, and whether for locomotive or stationary boilers.

SIGNALS.

A red flag by day, a red lantern by night, or any signal violently given, are signals of danger, on perceiving which the train must be brought to a full stop as soon as possible, and not proceed until it can be done with safety.

Two red flags by day, and two red lanterns by night, placed on the front of an engine, indicate that the engine is to be followed by an extra train.



A lantern raised and lowered vertically is a signal for starting; when swung at right angles, or across

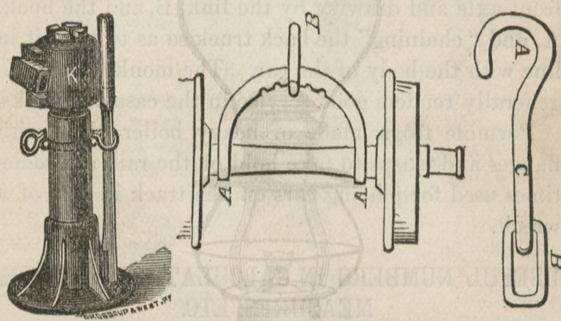
the track, to stop; when swung in a circle, back the train.

A sweeping parting of the hands, on a level with the eye, is a signal to go ahead. A downward motion of one hand, with extended arm, to stop. A beckoning motion of one hand, to back.

One short sound of the whistle is the signal to apply brakes; two, to let go brakes; three, to back up; four, to call in the flagman; five, for road crossings.

One stroke of the alarm-bell signifies stop; two, to go ahead; three, to back up.

WRECKING TOOLS.



A A represents a truck-axle and wheels. C is a bar of iron, about two by four inches, bent like the bail of a bucket, with a hook or turn on each end of it large enough to hook over an axle close to each wheel, and which is used in pulling cars on the track when they may be off on one side, or for "straightening" the track toward the point to which it is desired to pull the car, and pulling the car by this "bail" the track is kept directly in the line of draft.

There is a loose link, B, on the "bail," C, into which the hook or draft-rope is attached. When this link is put into the centre notch of the bail the axle of the truck will be held at right angles to the rope; and when put into the notch on either side of the centre, the axle will be held at a corresponding angle to the line of draft of the rope.

By this bail a car (or truck, or pair of wheels) can be pulled in almost any direction by putting it on the front axle and drawing by the link, B, and the hook, A, and "chaining" the back truck so as to keep it in line with the body of the car. The monkey-jack, K, generally renders good service in the case of wrecks.

Portable frogs, made of heavy boiler plate, with flanges and clasps to take hold of the rail, are sometimes used for placing cars on the track in case of a wreck.

USEFUL NUMBERS IN CALCULATING WEIGHTS, MEASURES, ETC.

Feet	multiplied by	.00019	equals	miles.
Yards	"	.0006	"	miles.
Links	"	.22	"	yards.
Links	"	.66	"	feet.
Feet	"	1.515	"	links.

Square inches	multiplied by	.007	equals	square feet.
Circular inches	"	.00546	"	square feet.
Square feet	"	.111	"	square yds.
Acres	"	4840	"	square yds.
Square yards	"	.0002066	"	acres.
Width in chains	"	.8	"	acres per m.
Cube feet	"	.037	"	cube yards.
Cube inches	"	.00058	"	cube feet.
U. S. bushels	"	.0461	"	cube yards.
U. S. bushels	"	1.2444	"	cube feet.
U. S. bushels	"	2150.42	"	cube inches.
Cube feet	"	.8036	"	U. S. bush's.
Cube inches	"	.000465	"	U. S. bush's.
U. S. gallons	"	.13367	"	cube feet.
U. S. gallons	"	231	"	cube inches.
Cube feet	"	7.48	"	U. S. galls.
Cylindrical feet	"	5.874	"	U. S. galls.
Cube inches	"	.004329	"	U. S. galls.
Cylindrical inches	"	.0034	"	U. S. galls.
Pounds	"	.009	"	cwt.
Pounds	"	.00045	"	tons.
Cubic foot of water	"	62.5	"	lbs. avoird.
Cubic inch of water	"	.03608	"	lbs. avoird.
Cylindr'l foot of water	"	49.1	"	lbs. avoird.
Cylindr'l inch of water	"	.02842	"	lbs. avoird.
U. S. gallons of water	"	13.44	"	1 cwt.
U. S. gallons of water	"	268.8	"	1 ton.
Cubic feet of water	"	1.8	"	1 cwt.
Cubic feet of water	"	35.88	"	1 ton.
Cylindr'l foot of water	"	5.875	"	U. S. galls.
Column of water, 12 in. high, 1 in. diameter			"	.341 lbs.
183.346 circular inches			"	1 square ft.
2200 cylindrical inches			"	1 cubic foot
French metres	multiplied by	3.28	"	feet.
Kilogrammes	"	2.205	"	avoird. lbs.
Grammes	"	.002205	"	avoird. lbs.

MENSURATION OF THE CIRCLE, CYLINDER, SPHERE, ETC.

1. The circle contains a greater area than any other plain figure bounded by an equal perimeter or outline.

2. The areas of circles are to each other as the squares of their diameters.

3. The diameter of a circle being 1, its circumference equals 3.1416.

4. The diameter of a circle is equal to .31831 of its circumference.

5. The square of the diameter of a circle being 1, its area equals .7854.

6. The square root of the area of a circle multiplied by 1.12837 equals its diameter.

7. The diameter of a circle multiplied by .8862, or the circumference multiplied by .2821, equals the side of a square of equal area.

8. The sum of the squares of half the chord and versed sine, divided by the versed sine, the quotient equals the diameter of corresponding circle.

9. The chord of the whole arc of a circle taken from eight times the chord of half the arc, one-third of the remainder equals the length of the arc ; or,

10. The number of degrees contained in the arc of a circle, multiplied by the diameter of the circle and by .008727, the product equals the length of the arc in equal terms of unity.

11. The length of the arc of a sector of a circle multiplied by its radius, equals twice the area of the sector.

12. The area of the segment of a circle equals the area of the sector, minus the area of a triangle whose vertex is the centre, and whose base equals the chord of the segment; or,

13. The area of a segment may be obtained by dividing the height of the segment by the diameter of the circle, and multiplying the corresponding tabular area by the square of the diameter.

14. The sum of the diameters of two concentric circles multiplied by their difference and by .7854, equals the area of the ring or space contained between them.

15. The sum of the thickness and internal diameter of a cylindric ring multiplied by the square of its thickness and by 2.4674, equals its solidity.

16. The circumference of a cylinder multiplied by its length or height, equals its convex surface.

17. The area of the end of a cylinder multiplied by its length, equals its solid contents.

18. The internal area of a cylinder multiplied by its depth, equals its cubical capacity.

19. The square of the diameter of a cylinder multiplied by its length, and divided by any other required length, the square root of the quotient equals the diameter of the other cylinder of equal contents or capacity.

20. The square of the diameter of a sphere multiplied by 3.1416, equals its convex surface.

21. The cube of the diameter of a sphere multiplied by .5236, equals its solid contents.

22. The height of any spherical segment or zone multiplied by the diameter of the sphere of which it is a part, and by 3.1416, equals the area or convex surface of the segment; or,

23. The height of the segment multiplied by the circumference of the sphere of which it is a part, equals the area.

24. The solidity of any spherical segment is equal to three times the square of the radius of its base, plus the square of its height, and multiplied by its height and by .5236.

25. The solidity of a spherical zone equals the sum of the squares of the radii of its two ends, and one-third the square of its height multiplied by the height and by 1.5708.

26. The capacity of a cylinder 1 foot in diameter and 1 foot in length equals 5.875 of a United States gallon.

27. The capacity of a cylinder 1 inch in diameter and 1 foot in length equals .0408 of a United States gallon.

28. The capacity of a cylinder 1 inch in diameter and 1 inch in length equals .0034 of a United States gallon

29. The capacity of a sphere 1 foot in diameter equals 3.9168 United States gallons.

30. The capacity of a sphere 1 inch in diameter equals .002267 of a United States gallon; hence,

31. The capacity of any other cylinder in United States gallons is obtained by multiplying the square of its diameter by its length, or the capacity of any other sphere by the cube of its diameter, and by the number of United States gallons contained as above in the unity of its measurement.

TABLE

OF DECIMAL EQUIVALENTS TO THE FRACTIONAL PARTS OF A GALLON OR AN INCH

(The inch or gallon being divided into 32 parts.)

Decimal.	Gallon or Inch.	Gills.	Pints.	Quarts.	Decimal.	Gallon or Inch.	Gills.	Pints.	Quarts.
.03125	$\frac{1}{32}$	1	$\frac{1}{4}$	$\frac{1}{8}$	.53125	$\frac{17}{32}$	17	$4\frac{1}{4}$	$2\frac{1}{8}$
.0625	$\frac{1}{16}$	2	$\frac{1}{2}$	$\frac{1}{4}$	.5625	$\frac{9}{16}$	18	$4\frac{1}{2}$	$2\frac{1}{4}$
.09375	$\frac{3}{32}$	3	$\frac{3}{4}$	$\frac{3}{8}$	.59375	$\frac{19}{32}$	19	$4\frac{3}{4}$	$2\frac{3}{8}$
.125	$\frac{1}{8}$	4	1	$\frac{1}{2}$	.625	$\frac{5}{8}$	20	5	$2\frac{1}{2}$
.15625	$\frac{5}{32}$	5	$1\frac{1}{4}$	$\frac{5}{8}$	.65625	$\frac{21}{32}$	21	$5\frac{1}{4}$	$2\frac{5}{8}$
.1875	$\frac{3}{16}$	6	$1\frac{1}{2}$	$\frac{3}{4}$	.6875	$\frac{11}{16}$	22	$5\frac{1}{2}$	$2\frac{3}{4}$
.21875	$\frac{7}{32}$	7	$1\frac{3}{4}$	$\frac{7}{8}$	.71875	$\frac{23}{32}$	23	$5\frac{3}{4}$	$2\frac{7}{8}$
.25	$\frac{1}{4}$	8	2	1	.75	$\frac{3}{4}$	24	6	3
.28125	$\frac{9}{32}$	9	$2\frac{1}{4}$	$1\frac{1}{8}$	.78125	$\frac{25}{32}$	25	$6\frac{1}{4}$	$3\frac{1}{8}$
.3125	$\frac{5}{16}$	10	$2\frac{1}{2}$	$1\frac{1}{4}$	.8125	$\frac{26}{32}$	26	$6\frac{1}{2}$	$3\frac{1}{4}$
.34375	$\frac{11}{32}$	11	$2\frac{3}{4}$	$1\frac{3}{8}$	.84375	$\frac{27}{32}$	27	$6\frac{3}{4}$	$3\frac{3}{8}$
.375	$\frac{3}{8}$	12	3	$1\frac{1}{2}$	.875	$\frac{7}{8}$	28	7	$3\frac{1}{2}$
.40625	$\frac{13}{32}$	13	$3\frac{1}{4}$	$1\frac{5}{8}$	.90625	$\frac{29}{32}$	29	$7\frac{1}{4}$	$3\frac{5}{8}$
.4375	$\frac{7}{16}$	14	$3\frac{1}{2}$	$1\frac{3}{4}$	.9375	$\frac{15}{16}$	30	$7\frac{1}{2}$	$3\frac{3}{4}$
.46875	$\frac{15}{32}$	15	$3\frac{3}{4}$	$1\frac{7}{8}$	.96875	$\frac{31}{32}$	31	$7\frac{3}{4}$	$3\frac{7}{8}$
.5	$\frac{1}{2}$	16	4	2	1.000	1	32	8	4

In multiplying decimals it is usual to drop all but the first two or three figures.

Application. — Required, the gallons in any cylindrical vessel. Suppose a vessel $9\frac{1}{2}$ inches deep, 9 inches diameter, and contents 2.6163 — that is, 2 gallons and $\frac{6163}{10000}$th part of a gallon. Now to ascertain this decimal of a gallon refer to the above table for the decimal that is nearest, which is .625, opposite to which is $\frac{5}{8}$th of a gallon, or 20 gills, or 5 pints, or $2\frac{1}{2}$ quarts; consequently the vessel contains 2 gallons and 5 pints.

Inches. — To find what part of an inch the .708 is refer to the above table for the decimal that is nearest, which is .71875, opposite to which is $\frac{23}{32}$, or nearly $\frac{3}{4}$ of an inch.

TABLE

ON FOLLOWING PAGES CONTAINING THE DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS OF EACH IN GALLONS AT 1 FOOT IN DEPTH.

1. Required, the circumference of a circle, the diameter being 5 inches.

In the column of circumferences, opposite the given diameter, stands 15.708 inches, the circumference required.

2. Required, the capacity, in gallons, of a cylinder, the diameter being 6 feet and depth 10 feet.

In the fourth column from the given diameter stands 211.4472, being the contents of a cylinder 6 feet in diameter and 1 foot in depth, which being multiplied by 10, gives the required contents, $2{,}114\frac{1}{2}$ gallons.

3. Any of the areas in feet multiplied by .03704, the product equals the number of cubic yards at 1 foot in depth.

4. The area of a circle in inches, multiplied by the length or thickness in inches and by .263, the product equals the weight in pounds of cast-iron.

(See page 245 for Decimal Equivalents to the fractional parts of a gallon and an inch.)

TABLE

OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS OF EACH IN GALLONS AT 1 FOOT IN DEPTH.

Diameter.	Circumference, Inches.	Area, Inches.	Gallons.
1 in.	3.1416	.7854	.04084
2 "	6.2832	3.1416	.16333
3 "	9.4248	7.0686	.36754
4 "	12.566	12.566	.65343
5 "	15.708	19.635	1.02102
6 "	18.849	28.274	1.47025
7 "	21.991	38.484	2.00117
8 "	25.132	50.265	2.61378
9 "	28.274	63.617	3.30808
10 "	31.416	78.540	4.08408
11 "	34.557	95.033	4.94172

TABLE—(*Continued*)

OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS OF EACH IN GALLONS AT 1 FOOT IN DEPTH.

Diameter.	Circumference.	Area in Feet.	Gals., 1 ft. in Depth.
1 ft.	3 ft. 1⅝ in.	.7854	5.8735
2 "	6 " 3⅜ "	3.1416	23.4940
3 "	9 " 5 "	7.0686	52.8618
4 "	12 " 6¾ "	12.5664	93.9754
5 "	15 " 8½ "	19.6350	146.8384
6 "	18 " 10⅛ "	28.2744	211.4472
7 "	21 " 11⅞ "	38.4846	287.8032
8 "	25 " 1½ "	50.2656	375.9062
9 "	28 " 3¼ "	63.6174	475.7563
10 "	31 " 5 "	78.5400	587.3534
11 "	34 " 6⅝ "	95.0334	710.6977
12 "	37 " 8⅜ "	113.0976	848.1890
13 "	40 " 10 "	132.7326	992.6274
14 "	43 " 11¾ "	153.9384	1151.2129
15 "	47 " 1½ "	176.7150	1321.5454
16 "	50 " 3⅛ "	201.0624	1503.6250
17 "	53 " 4⅞ "	226.9806	1697.4516
18 "	56 " 6½ "	254.4696	1903.0254
19 "	59 " 8¼ "	283.5294	2120.3462
20 "	62 " 9⅞ "	314.1600	2349.4141
21 "	65 " 11⅝ "	346.3614	2590.2290
22 "	69 " 1⅜ "	380.1336	2842.7910
23 "	72 " 3 "	415.4766	3107.1001
24 "	75 " 4¾ "	452.3904	3383.1563
25 "	78 " 6⅜ "	490.8750	3670.9596
26 "	81 " 8⅛ "	530.9304	3970.5098
27 "	84 " 9⅞ "	572.5566	4281.8072
28 "	87 " 11½ "	615.7536	4604.8517
29 "	91 " 1¼ "	660.5214	4939.6432
30 "	94 " 2⅞ "	706.8600	5286.1818

TABLE

SHOWING THE WEIGHT OF WATER IN PIPE OF VARIOUS DIAMETERS 1 FOOT IN LENGTH.

Diameter in Inches.	Weight in Pounds	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.
3	3	12¼	51	22½	172½
3¼	3½	12½	53¼	23	180¼
3½	4¼	12¾	55½	23½	188¼
3¾	4¾	13	57½	24	196¼
4	5½	13¼	59¾	24½	204½
4¼	6¼	13½	62¼	25	213
4½	7	13¾	64½	25½	221½
4¾	7¾	14	66¾	26	230½
5	8½	14¼	69¼	26½	239½
5¼	9¼	14½	71½	27	248½
5½	10½	14¾	74¼	27½	257¾
5¾	11¼	15	76¾	28	267¼
6	12¼	15¼	79¼	28½	276¾
6¼	13¼	15½	82	29	286½
6½	14½	15¾	84½	29½	296½
6¾	15½	16	87¼	30	306¾
7	16¾	16¼	90	30½	317¼
7¼	18	16½	92¼	31	327½
7½	19¼	16¾	95½	31½	338¼
7¾	20½	17	98½	32	349
8	21¾	17¼	101½	32½	360
8¼	23¼	17½	104½	33	371¼
8½	24½	17¾	107½	33½	382½
8¾	26	18	110½	34	394
9	27½	18¼	113½	34½	405¾
9¼	29¼	18½	116½	35	417½
9½	30¾	18¾	119¾	35½	429½
9¾	32½	19	123	36	441¾
10	34	19¼	126¼	36½	454
10¼	35½	19½	129½	37	466½
10½	37½	19¾	132	37½	479¼
10¾	39¼	20	136¼	38	492¼
11	41¼	20½	143¼	38½	505¼
11¼	44¼	21	150¼	39	518½
11½	45	21½	157½	39½	531¾
11¾	47	22	165	40	545½
12	49				

RULES.

Rule. — *For finding the Quantity of Water in a Steam-boiler or any Cylindrical Vessel in Cubic Inches.* — Multiply the internal area of the head or base in inches by the length in inches; the product will be the number of cubic inches of water in the boiler. Divide this product by 1728, and the quotient will be the number of cubic feet of water in the boiler or cylinder.

Rule.—*To find the Requisite Quantity of Water for a Boiler.* — Add 15 to the pressure of steam per square inch; divide the sum by 18; multiply the quotient by .24; the product is the quantity in U. S. gallons per minute for each horse-power.

Rule.—*To find the Height of a Column of Water to supply a Steam-boiler against any Pressure of Steam required.*—Multiply the pressure, in pounds, upon a square inch of boiler, by 2.5; the product will be the height in feet above the surface of the water in the boiler.

Rule.—*To find the Time a Cylindrical Vessel will take in filling when a known Quantity of Water is going in and a known Quantity of that Water is going out in a given time.* — Divide the contents of the cistern, in gallons, by the difference of the quantity going in and the quantity going out per hour, and the quotient is the time in hours and parts that the cistern will take in filling.

Pressure of Water. — The weight of water or of other liquids is as the quantity, but the pressure exerted is as the vertical height.

Fluids press equally in all directions; hence, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid as the area of the vessel is to the sectional area of the column.

Lateral Pressure. — The lateral pressure of water on the sides of a vessel in which it is contained is equal to the product of the length multiplied by half the square of the depth and by the weight of the water in cubic unity of dimensions.

Discharge of Water.—In circular apertures in a thin plate on the bottom or side of a reservoir, the issuing stream tends to converge to a point distant at about ½ its diameter from outside the orifice, reducing the quantity nearly ⅜ths from the quantity due to the velocity corresponding to the height.

When water issues from a short tube, the flow is less contracted than in the former case, as 16 to 13.

With a conical aperture, whose greater base is the aperture, the height of the frustrum being half the diameter of the aperture, and the area of the small end to the area of the large end as 10 to 16, there will be no contraction of the vein. Hence this form gives the greatest flow.

The quantity of water discharged during the same time by the same orifices under different heads, are nearly as the square roots of the corresponding heights of the water in the reservoir above the surface of the orifices.

Small orifices, on account of friction, discharge proportionately less fluid than those which are larger and of the same figure, under the same pressure.

Circular apertures are the most efficacious, having less rubbing surface under the same area.

If the cylindrical horizontal tube through which water is discharged be of greater length than the diameter, the discharge is much increased — can be increased, to advantage, to four times the diameter of the orifice.

RULES FOR FINDING THE ELASTICITY OF STEEL SPRINGS.

Rule I. — *To find the Elasticity of a given Steel-plate Spring.*—Breadth of the plate in inches multiplied by the cube of the thickness in $\frac{1}{16}$ inch, and by the number of plates; divide the cube of the span in inches by the product so found, and multiply by 1.66. The result equals the elasticity in $\frac{1}{16}$ of an inch per ton of load.

Rule 2. — *To find Span due to a given Elasticity, and the Number and Size of Plate.*—Multiply the

elasticity in sixteenths per ton, by the breadth of the plate in inches, and divide by the cube of the thickness in inches, and by the number of plates; divide by 1.66, and find the cube root of the quotient. The result equals the span in inches.

Rule 3.—*To find the Number of Plates due to a given Elasticity, the Span and Size of the Plates.*—Multiply the cube of the span in inches by 1.66; multiply the elasticity in sixteenths by the breadth of the plate in inches, and by the cube of the thickness in sixteenths; divide the former product by the latter. The quotient is the number of plates.

Rule 4. —*To find the Working Strength of a given Steel-plate Spring.*—Multiply the breadth of plate in inches by the square of the thickness in sixteenths, and by the number of plates; multiply also the working span in inches by 11.3; divide the former product by the latter. The result equals the working strength in tons burden.

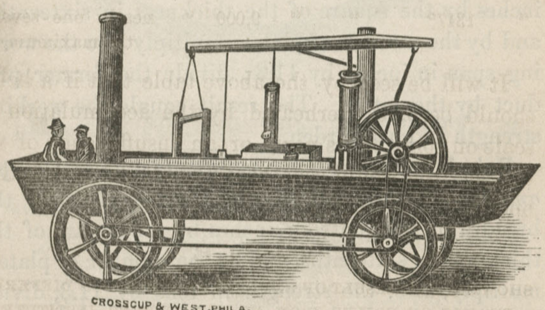
Rule 5.—*To find the Span due to a given Strength and the Number and Size of Plate.*—Multiply the breadth of the plate in inches by the square of the thickness in sixteenths, and by the number of plates, multiply, also, the strength in tons by 11.3, divide the former product by the latter. The result equals the working span in inches.

Rule 6. —*To find the Number of Plates due to a given Strength, Span and Size of Plate.*—Multiply the strength in tons by span in inches, and divide by

11.3; multiply also the breadth of plate in inches by the square of the thickness in sixteenths; divide the former product by the latter. The result equals the number of plates.

The span is that due to the form of the spring loaded. Extra thick plates must be replaced by an equivalent number of plates of the ruling thickness, before applying the rule. To find this, multiply the number of extra plates by the ruling thickness; conversely, the number of plates of the ruling thickness to be removed for a given number of extra plates, may be found in the same way.

Springs were applied to locomotives in 1830, by T. Hackworth.



OLIVER EVANS'S LOCOMOTIVE—1804.

To Oliver Evans belongs the honor of having built and put in operation the first high-pressure steam-engine on record.

TABLE

DEDUCTED FROM EXPERIMENTS ON IRON PLATES FOR STEAM BOILERS, BY THE FRANKLIN INSTITUTE, PHILADA.

Iron boiler-plate was found to increase in tenacity as its temperature was raised, until it reached a temperature of 550° above the freezing-point, at which point its tenacity began to diminish.

At	32° to 80°	tenacity is	56,000	lbs.	or one-seventh below its maximum.
"	570°	" "	66,000	"	the maximum.
"	720°	" "	55,000	"	the same nearly as at 30°.
"	1050°	" "	32,000	"	nearly one-half the maximum.
"	1240°	" "	22,000	"	nearly one-third the maximum.
"	1317°	" "	9,000	"	nearly one-seventh the maximum.

It will be seen by the above table that if a boiler should become overheated, by the accumulation of scale on some of its parts or an insufficiency of water, the iron would soon become reduced to less than one-half its strength.

TABLE

SHOWING THE RESULT OF EXPERIMENTS MADE ON DIFFERENT BRANDS OF BOILER IRON AT THE STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N. J.

Thirty-three experiments were made upon iron taken from the exploded steam-boiler of the ferry-boat Westfield. The following were the results:

	Lbs. per sq. inch
Average breaking weight	41,653
16 experiments made upon high grades of American boiler-plate.	
Average breaking weight	54,123
15 experiments made upon high grades of American flange-iron.	
Average breaking weight	42,144
6 experiments made upon English Bessemer steel.	
Average breaking weight	82,621
5 experiments made upon English Lowmoor boiler-plate.	
Average breaking weight	58,984
6 experiments made upon samples of tank iron from different manufacturers.	
Average breaking weight, No. 1 . . .	43,831
" " " No. 2 . . .	42,011
" " " No. 3 . . .	41,249
2 experiments made on iron taken from the exploded steam-boiler of the Red Jacket.	
Average breaking weight	49,000

It will be noticed that the above experiments reveal a great variation in the strength of boiler-plate of different grades of iron, and furnish conclusive evidence that the tensile strength of boiler-iron ought to be taken at 50,000 pounds to the square inch instead of 60,000.

TABLE

SHOWING THE ACTUAL EXTENSION OF WROUGHT-IRON AT VARIOUS TEMPERATURES.

Deg. of Fahr.	Length.	
32°	1.	
212	1.0011356	
392	1.0025757	Surface becomes straw-colored, deep yellow, crimson, violet, purple, deep blue, bright blue.
672	1.0043253	
752	1.0063894	
932	1.0087730	Surface becomes dull, and then bright red.
112	1.0114811	
1652	1.0216024	Bright red, yellow, welding heat, white heat.
2192	1.0348242	
2732	1.0512815	
2912	cohesion destroyed. Fusion perfect.	

TABLE

SHOWING THE TENSILE STRENGTH OF VARIOUS QUALITIES OF CAST-IRON.

American Cast-Iron.

	Breaking weight of a square inch bar.
Common pig-iron, ...	15,000
Good common castings, ...	20,000
Cast-iron "	20,834
" "	19,200
" "	27,700
Gun-heads, specimen from, ...	24,000
" "	39,500
Greenwood cast-iron, ...	21,300
" " (after third melting,) .	45,970
Mean of American cast-iron, ...	31,829
Gun-metal, mean, ...	37,232

English Cast-Iron.

Lowmoor, ...	14,076
Clyde, No. 1, ...	16,125
Clyde, No. 3, ...	23,468
Calder, No. 1, ...	13,735
Stirling, mean, ...	25,764
Mean of English, ...	19,484
Stirling, toughened iron, ...	28,000
Carron No. 2, cold-blast, ...	16,683
" " 2, hot-blast, ...	13,505
" " 3, cold-blast, ...	13,200
" " 3, hot-blast, ...	17,755
Davon, No. 3, hot-blast, ...	21,907
Buffery, No. 1, cold-blast, ...	17,466
" " 1, hot-blast, ...	13,437
Cold-Talon (North Wales), No. 2, cold-blast, .	18,855
" " " 2, hot-blast, .	16,676

TABLE

SHOWING THE TENSILE STRENGTH OF VARIOUS QUALITIES OF WROUGHT-IRON.

American Wrought-Iron.

	Breaking weight of a square inch bar.
From Salisbury, Conn.,	58,000
" " "	66,000
" Pittsfield, Mass.,	57,000
" Bellefonte, Pa.,	58,000
" Maramec, Mo.,	43,000
" " "	53,000
" Centre County, Pa.,	58,400
" Lancaster County, Pa.,	58,061
" Carp River, Lake Superior,	89,582
" Mountain, Mo., charcoal bloom,	90,000
American, hammered,	53,900
Chain-iron,	43,000
Rivets,	53,300
Bolts,	52,250
Boiler-plates,	50,000
" "	60,000
Average boiler-plates,	55,000
" joints, double-riveted,	35,700
" " single "	28,600
Chrome steel, highest strength,	198,910
" lowest "	163,760
" average "	180,000

English and other Wrought-Irons.

Iron, English bar,	56,000
" mean of English,	53,900
" rivets,	65,000
Lowmoor iron,	56,100

English and other Wrought-Irons — (Continued).

	Breaking weight of a square inch bar.
Lowmoor iron plates,	57,881
Bowling plates,	53,488
Glasgow best boiler,	56,317
" ship plates,	53,870
Yorkshire plates,	57,724
Staffordshire plates,	43,821
Derbyshire plates,	48,563
Bessemer wrought-iron,	65,253
" " "	76,195
" " "	82,110
Russian " "	59,500
" " "	76,084
Swedish " "	58,084

TABLE

SHOWING THE TENSILE STRENGTH OF VARIOUS QUALITIES OF STEEL PLATES.

Mersey Co., puddled steel,	108,906
" ship-plates,	99,468
Blochairn puddled steel,	106,394
" boiler-plates,	89,447
Naylor, Vickers & Co., cast,	87,972
" " " "	95,196
T. Turton & Son,	95,360
Moss & Gambles,	81,588
Shortridge, Howell & Co.,	108,900
Homogeneous metal,	105,732
" " 2d quality,	81,662
Bessemer steel,	148,324
" "	154,825
" "	157,881

CENTRAL AND MECHANICAL FORCES AND DEFINITIONS.

Adhesion. — The measure of the friction between the tires of the driving-wheels and the surface of the rails.

Acceleration.—Acceleration is the increase of velocity in a moving body caused by the continued action of the motive force. When bodies in motion pass through equal spaces in equal times, or, in other words, when the velocity of the body is the same during the period that the body is in motion, it is termed uniform motion.

Angle of Friction.—That pitch of grade at which a loaded car would just stand without descending, being kept at rest by the friction of its bearings.

Animal Strength. — As horses were formerly employed for the same purposes that water-wheels, windmills, and steam-engines now are, it has become usual to calculate the effect of these machines as equivalent to so many horses; and animal strength becomes thus a sort of measure of mechanical force.

Axles. — The railway axle may be considered as having certain relations to a girder in principle. Girders generally have their two ends resting on two points of support, and the load is either located at fixed distances from the props, or dispersed over the whole surface; in the case of the axle the wheels may be considered the props and the journals the loaded parts.

Attraction. — A tendency which certain bodies have to approach and adhere to each other. There are several kinds of attraction, as of gravitation, cohesion, capillary, chemical, electrical, etc.

Cohesion is that quality of a body which causes its particles to adhere to each other, and to resist being torn apart.

Crushing Strength is the resistance which a body opposes to being battered or flattened down by any weight placed upon it.

Central or Centrifugal Force. — The tendency which bodies in motion have to recede from their centres is called the centrifugal force.

Detrusive Strength is the resistance which a body offers to being clipped or shorn into two parts by such instruments as shears or scissors.

Force. — Force is the cause of motion or change of motion in material bodies. Every change of motion, viz., every change in the velocity of a body must be regarded as the effect of a force. On the other hand, rest, or the invariability of the state of motion of a body, must not be attributed to the absence of forces, for equal opposite forces destroy each other and produce no effect.

Centripetal Force.—Centripetal force is the force which has a tendency in a moving body to approach the centre of motion or counteract the centrifugal force.

Friction is the resistance occasioned to the motion of a body when pressed upon the surface of another body which does not partake of its motion.

Gravity, or Centre of Gravity. — The forces with which all bodies tend to fall to the earth may be considered parallel: hence, every body may be considered as acted on by a system of parallel forces, whose results may be found; and these forces, in all positions of the body, act on the same points in the same vertical direction. There is, therefore, in every body a point through which the resultant always passes, in whatever position it is placed. The point is called the centre of gravity of the body.

Gyration.—The centre of gyration is that point in which, if all the matter contained in a revolving system were collected, the same angular velocity will be generated in the same time by a given force acting at any place as would be generated by the same force acting similarly in the body or system itself.

Hydrodynamics.—Hydrodynamics is that branch of general mechanics which treats of the equilibrium and motion of fluids. The terms *hydrostatics* and *hydrodynamics* have corresponding signification to the statics and dynamics in the mechanics of solid bodies, viz., hydrostatics is that division of the science which treats of equilibrium of fluids, and hydrodynamics that which relates to their forces and motion.

Inertia. — Inertia is that property of matter by which it tends, when at rest to remain so, and when in motion to continue in motion.

Impetus. — The product of the mass and velocity of a moving body, considered as instantaneous, in distinction from momentum, with reference to time, and force, and also to capacity of continuing its motion.

Inclined Plane. — One of the mechanical powers; a plane which forms an angle with the horizon. The force which accelerates the motion of a heavy body on an inclined plane, is to the force of gravity as the sine of the inclination of the plane to the radius, or, as the height of the plane to its length.

Indicator.—The very important and useful instrument which has contributed so very materially to the perfection and efficiency of our modern steam-engines.

Logarithms.—The logarithm of a number is the exponent of a power to which another given invariable number must be raised in order to produce the first number. Thus in the common system of logarithms, in which the invariable number is 10, the logarithm of 1000 is 3, because 10 raised to the third power is 1000.

Hyperbolic Logarithms. — A system of logarithms, so called because the numbers express the areas between the asymptote and curve of the hyperbola.

Mechanical Power. — Power is a compound of weight multiplied by its velocity; it cannot be increased by mechanical means.

Power, as the term is only properly used by engineers, is the amount of work done in any given example in some known time. Its unit is called the horse-power.

Momentum, in mechanics, is the same with impetus or quantity of motion, and is generally estimated by the product of the velocity and mass of the body.

Motion. — Motion, in mechanics, is a change of place, or it is that affection of matter by which it passes from one point of space to another.

Motion is of various kinds, as follows:

Absolute motion is the absolute change of place in a moving body independent of any other motion whatever.

Accelerated motion is that which is continually receiving constant accessions of velocity.

Angular motion is the motion of a body as referred to a centre, about which it revolves.

Compound motion is that which is produced by two or more powers acting in different directions.

Uniform motion is when the body moves continually with the same velocity, passing over equal spaces in equal times.

Natural motion is that which is natural to bodies or that which arises from the action of gravity.

Relative motion is the change of relative place in one or more moving bodies.

Retarded motion is that which suffers continual diminution of velocity, the laws of which are reverse of those for accelerated motion.

Oscillation, or the Centre of Oscillation. — The centre of oscillation is that point in a vibrating body into which, if the whole were concentrated and attached to the same axis of motion, it would vibrate in the same time the body does in its natural state. The centre of oscillation is situated in a right line passing through the centre of gravity, and perpendicular to the axis of motion.

Pendulum. — If any heavy body, suspended by an inflexible rod from a fixed point, be drawn aside from the vertical position, and then let fall, it will descend in the arc of a circle, of which the point of suspension is the centre.

Perpetual Motion. — In mechanics, a machine which, when set in motion, would continue to move forever, or, at least, until destroyed by the friction of its parts, without the aid of any exterior cause.

Percussion, or the Centre of Percussion. — The centre of percussion is that point in a body revolving about an axis at which, if it struck an immovable obstacle, all its motion would be destroyed, or it would not incline either way.

Prime Movers are those machines from which we obtain power, through their adaptation to the transformation of some available natural force into that kind of effort which develops mechanical power.

Pneumatics. — The science which treats of the mechanical properties of elastic fluids, and particularly of atmospheric air.

Specific Gravity. — The specific gravity of a body is the ratio of its weight to an equal volume of some other body assumed as a conventional standard. The standard usually adopted for solids and liquids is rain, or distilled water at a common temperature.

Strength is the resistance which a body opposes to disintegration or separation of its parts.

Torsion, in mechanics, is the twisting or wrenching of a body by the exertion of a lateral force.

Torsional strength is the resistance which a body offers to any external force which attempts to twist it.

Transverse strength is the resistance to bending or flexure.

Velocity, or Virtual Velocity.—Virtual velocity, in mechanics, is the velocity which a body in equilibrium would actually acquire during the first instant of its motion, in case of the equilibrium being disturbed.

Weights and Measures.—The weights and measures of this country are identical with those of England. In both countries they repose in fact upon actually existing masses of metal (brass), which have been individually declared by law to be the units of the system.

Work.—Work is force acting through space, and is measured by multiplying the measure of the force by the measure of the space.

TABLE

CONTAINING DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES FROM $\frac{1}{16}$ OF AN INCH TO 10 INCHES, ADVANCING BY $\frac{1}{16}$ OF AN INCH; AND BY $\frac{1}{8}$ OF AN INCH FROM 10 INCHES TO 50 INCHES DIAMETER.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.
1/16	.1963	.0030	15/16	6.0868	2.9483
1/8	.3927	.0122	2	6.2832	3.1416
3/16	.5890	.0276	1/16	6.4795	3.3411
1/4	.7854	.0490	1/8	6.6759	3.5465
5/16	.9817	.0767	3/16	6.8722	3.7582
3/8	1.1781	.1104	1/4	7.0686	3.9760
7/16	1.3744	.1503	5/16	7.2640	4.2001
1/2	1.5708	.1963	3/8	7.4613	4.4302
9/16	1.7671	.2485	7/16	7.6576	4.6664
5/8	1.9635	.3068	1/2	7.8540	4.9087
11/16	2.1598	.3712	9/16	8.0503	5.1573
3/4	2.3562	.4417	5/8	8.2467	5.4119
13/16	2.5525	.5185	11/16	8.4430	5.6727
7/8	2.7489	.6013	3/4	8.6394	5.9395
15/16	2.9452	.6903	13/16	8.8357	6.2126
1	3.1416	.7854	7/8	9.0321	6.4918
1/16	3.3379	.8861	15/16	9.2284	6.7772
1/8	3.5343	.9940	3	9.4248	7.0686
3/16	3.7306	1.1075	1/16	9.6211	7.3662
1/4	3.9270	1.2271	1/8	9.8175	7.6699
5/16	4.1233	1.3529	3/16	10.0138	7.9798
3/8	4.3197	1.4848	1/4	10.2120	8.2957
7/16	4.5160	1.6229	5/16	10.4065	8.6179
1/2	4.7124	1.7671	3/8	10.6029	8.9462
9/16	4.9087	1.9175	7/16	10.7992	9.2806
5/8	5.1051	2.0739	1/2	10.9956	9.6211
11/16	5.3014	2.2365	9/16	11.1919	9.9678
3/4	5.4978	2.4052	5/8	11.3883	10.3206
13/16	5.6941	2.5801	11/16	11.5846	10.6796
7/8	5.8905	2.7611	3/4	11.7810	11.0446

TABLE—(*Continued*)

CONTAINING DIAMETERS, CIRCUMFERENCES, ETC.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.
13/16	11.9773	11.4159	15/16	18.6532	27.6884
7/8	12.1737	11.7932	6	18.8496	28.2744
15/16	12.3700	12.1768	1/16	19.0459	28.8665
4	12.5664	12.5664	1/8	19.2423	29.4647
1/16	12.7627	12.9622	3/16	19.4386	30.0798
1/8	12.9591	13.3640	1/4	19.6350	30.6796
3/16	13.1554	13.7721	5/16	19.8313	31.2964
1/4	13.3518	14.1862	3/8	20.0277	31.9192
5/16	13.5481	14.6066	7/16	20.2240	32.5481
3/8	13.7445	15.0331	1/2	20.4204	33.1831
7/16	13.9408	15.4657	9/16	20.6167	33.8244
1/2	14.1372	15.9043	5/8	20.8131	34.4717
9/16	14.3335	16.3492	11/16	21.0094	35.1252
5/8	14.5299	16.8001	3/4	21.2058	35.7848
11/16	14.7262	17.2573	13/16	21.4021	36.4505
3/4	14.9226	17.7205	7/8	21.5985	37.1224
13/16	15.1189	18.1900	15/16	21.7948	37.8005
7/8	15.3153	18.6655	7	21.9912	38.4846
15/16	15.5716	19.1472	1/16	22.1875	39.1749
5	15 7080	19.6350	1/8	22.3839	39.8713
1/16	15.9043	20.1290	3/16	22.5802	40.5469
1/8	16.1007	20.6290	1/4	22.7766	41.2825
3/16	16.2970	21.1252	5/16	22.9729	41.9974
1/4	16.4934	21.6475	3/8	23.1693	42.7184
5/16	16.6897	22.1661	7/16	23.3656	43.4455
3/8	16.8861	22.6907	1/2	23.5620	44.1787
7/16	17.0824	23.2215	9/16	23.7583	44.9181
1/2	17.2788	23.7583	5/8	23.9547	45.6636
9/16	17.4751	24.3014	11/16	24.1510	46.4153
5/8	17.6715	24.8504	3/4	24.3474	47.1730
11/16	17.8678	25.4058	13/16	24.5437	47.9370
3/4	18.0642	25.9672	7/8	24.7401	48.7070
13/16	18.2605	26.5348	15/16	24.9364	49.4833
7/8	18.4569	27.1085	8	25.1328	50.2656

TABLE—(*Continued*)

CONTAINING DIAMETERS, CIRCUMFERENCES, ETC.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.
1/16	25.3291	51.0541	3/8	32.5941	84.5409
1/8	25.5255	51.8486	1/2	32.9868	86.5903
3/16	25.7218	52.8994	5/8	33.3795	88.6643
1/4	25.9182	53.4562	3/4	33.7722	90.7627
5/16	26.1145	54.2748	7/8	34.1649	92.8858
3/8	26.3109	55.0885	11	34.5576	95.0334
7/16	26.5072	55.9138	1/8	34.9503	97.2053
1/2	26.7036	56.7451	1/4	35.3430	99.4021
9/16	26.8999	57.5887	3/8	35.7357	101.6234
5/8	27.0963	58.4264	1/2	36.1284	103.8691
11/16	27.2926	59.7762	5/8	36.5211	106.1394
3/4	27.4890	60.1321	3/4	36.9138	108.4342
13/16	27.6853	60.9943	7/8	37.3065	110 7536
7/8	27.8817	61.8625	12	37.6992	113.0976
15/16	28.0780	62.7369	1/8	38.0919	115.4660
9	28.2744	63.6174	1/4	38.4846	117.8590
1/16	28.4707	64.5041	3/8	38.8773	120.2766
1/8	28.6671	65.3968	1/2	39.2700	122.7187
3/16	28.8634	66.2957	5/8	39.6627	125.1854
1/4	29.0598	67.2007	3/4	40.0554	127.6765
5/16	29.2561	68.1120	7/8	40.4481	130.1923
3/8	29.4525	69.0293	13	40 8408	132.7326
7/16	29.6488	69.9528	1/8	41.2338	135.2974
1/2	29.8452	70.8823	1/4	41.6262	137.8867
9/16	30.0415	71.8181	3/8	42.0189	140.5007
5/8	30.2379	72.7599	1/2	42.4116	143.1391
11/16	30.4342	73.7079	5/8	42.8043	145.8021
3/4	30.6306	74.6620	3/4	43.1970	148.4896
13/16	30.8269	75.6223	7/8	43.5897	151.2017
7/8	31.0233	76.5887	14	43.9824	153.9384
15/16	31.2196	77.5613	1/8	44.3751	156.6995
10	31.4160	78.5400	1/4	44.7676	159.4852
1/8	31.8087	80.5157	3/8	45.1605	162.2956
1/4	32.2014	82.5160	1/2	45.5532	165.1303

TABLE—(*Continued*)

CONTAINING DIAMETERS, CIRCUMFERENCES, ETC.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.
⅝	45.9459	167.9896	⅞	59.2977	279.8110
¾	46.3386	170.8735	19	59.6904	283.5294
⅞	46.7313	173.7820	⅛	60.0831	287.2723
15	47.1240	176.7150	¼	60.4758	291.0397
⅛	47.5167	179.6725	⅜	60.8685	294.8312
¼	47.9094	182.6545	½	61.2612	298.6483
⅜	48.3021	185.6612	⅝	61.6539	302.4894
½	48.6948	188.6923	¾	62.0466	306.3550
⅝	49.0875	191.7480	⅞	62.4393	310.2452
¾	49.4802	194.8282	20	62.8320	314.1600
⅞	49.8729	197.9330	⅛	63.2247	318.0992
16	50.2656	201.0624	¼	63.6174	322.0630
⅛	50.6583	204.2162	⅜	64.0101	326.0514
¼	51.0510	207.3946	½	64.4028	330.0643
⅜	51.4437	210.5976	⅝	64.7955	334.1018
½	51.8364	213.8251	¾	65.1882	338.1637
⅝	52.2291	217.0772	⅞	65.5809	342.2503
¾	52.6218	220.3537	21	65.9736	346.3614
⅞	53.0145	223.6549	⅛	66.3663	350.4970
17	53.4072	226.9806	¼	66.7590	354 6571
⅛	53.7999	230.3308	⅜	67.1517	358.8419
¼	54.1926	233.7055	½	67.5444	363.0511
⅜	54.5853	237.1049	⅝	67.9371	367.2849
½	54.9780	240.5287	¾	68.3298	371.5432
⅝	55.3707	243.9771	⅞	68.7225	375.8261
¾	55.7634	247.4500	22	69.1152	380.1336
⅞	56.1561	250.9475	⅛	69.5079	384.4665
18	56.5488	254.4696	¼	69.9006	388.8220
⅛	56.9415	258.0161	⅜	70.2933	393.2081
¼	57.3342	261.5872	½	70.6860	397.6087
⅜	57.7269	265.1829	⅝	71.0787	402.0388
½	58.1196	268.8031	¾	71.4714	406.4935
⅝	58.5123	272.4479	⅞	71.8641	410.9728
¾	58.9056	276.1171	23	72.2568	415.4766

TABLE—(*Continued*)

CONTAINING DIAMETERS, CIRCUMFERENCES, ETC.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.	Inches.	Inches.	Inch.	Inches.	Inches.
⅛	72.6495	420.0049	⅛	78.9327	495.7950
¼	73.0422	424.5577	¼	79.3254	500.7415
⅜	73.4349	429.1352	⅜	79.7181	505.7117
½	73.8276	433.7371	½	80.1108	510.7063
⅝	74.2203	438.3636	⅝	80.5035	515.7255
¾	74.6130	443.0146	¾	80.8962	520.7692
⅞	75.0057	447.6992	⅞	81.2889	525.8375
24	75.3984	452.3904	26	81.6816	530.9304
⅛	75.7911	457.1150	⅛	82.0743	536.0477
¼	76.1838	461.8642	¼	82.4670	541.1896
⅜	76.5765	466.6380	⅜	82.8597	546.3561
½	76.9692	471.4363	½	83.2524	551.5471
⅝	77.3619	476.2592	⅝	83.6451	556.7627
¾	77.7546	481.1065	¾	84.0378	562.0027
⅞	78.1473	485.9785	⅞	84.4305	567.2674
25	78.5400	490 8750			

To find the circumferences of larger circles, multiply the diameter by 3.1416.

For areas of larger circles, multiply the square of the diameter by .7854.

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

To find the diameter when the area is given, divide the area by the decimal .7854, and extract the square root of the quotient; that will give the diameter.

INCRUSTATION IN STEAM-BOILERS.

All waters contain more or less mineral matter, which is acquired by percolation through the earth's surface, and consists principally of carbonate of lime and magnesia, sulphate of lime and chloride of sodium in solution, clay, sand, and vegetable matter in suspension.

Some waters contain far less mineral ingredients than others — such as rain-water, the water of lakes and large rivers, whilst wells, springs, and creeks hold large quantities in solution.

When such water is boiled, the carbonic acid is driven off, and the carbonates, deprived of their solvents, are rapidly precipitated in a finely crystallized form, tenaciously adhering to the surface of the iron. Chloride of sodium, and all such soluble salts, are precipitated in the same way by supersaturation. This combined deposit, of which carbonate of lime forms the greater part, remains adherent to the inner surface of the boiler, undisturbed by the force of the most violent boiling currents.

Gradually this accumulation becomes harder and thicker, until it is as dense as porcelain, thereby preventing the proper heating of the water by any fire that can be placed in the furnace. The high temperature necessary to heat water through thick scale will sometimes convert the scale into a substance resembling glass.

The evil effect of scale in steam-boilers is due to the fact that it is a non-conductor of heat. The conducting power of scale compared with that of iron is as 1 to 37; consequently a greater amount of fuel is required to heat water in an incrusted boiler than if the same boiler were clean.

Scale $\frac{1}{16}$ of an inch thick will require an expenditure of fifteen per cent. more fuel. This expenditure increases as the scale becomes thicker; thus, when it is a quarter of an inch thick, sixty per cent. more fuel is needed to raise water in a boiler to any given heat. If the boiler is badly scaled, the fire-surface of the boiler must be heated to a temperature according to the thickness of the scale.

For example: To raise steam to a pressure of 90 pounds, the water must be heated to a temperature of 324° Fah. If a quarter of an inch of scale intervenes between the shell and the water, it would be necessary to heat the fire-surface of the boiler nearly 600°, or 100° Fah. above the maximum strength of iron. Now, it is a well-known fact that the higher the temperature at which iron is kept, the more rapidly it oxidizes, and is made liable at any time to bulge or crack by internal pressure, and is often the cause of explosions.

At a meeting of the Railway Mechanics' Association, held at Louisville, Kentucky, in 1871, the committee to whom was referred the subject of boiler incrustations reported that they had prepared and issued, through the secretary of the association, a circular of questions to all the master mechanics of various railroads throughout the country, in order to elicit such information as they might possess on this subject.

In compliance therewith, communications had been received from over sixty master mechanics, and the information so obtained was very extensive and valuable, confirming in substance the theory advanced in a paper read in the convention last year, to the effect that the only effectual way to prevent incrustation is to purify the water, if possible, before it is allowed to enter the boiler.

To this end the committee directed its efforts, and had given special attention to the reports of those who have experimented, with a view thereby of ascertaining the best and cheapest mode of accomplishing the same. From all communications received, it is found that most of the roads located in the Eastern and Southern States are troubled but little with incrustation, while those in Middle States are variously affected — some suffering greatly, others none at all.

Western roads suffer most, many of them finding it necessary, in order to maintain average economy in fuel and reasonable safety to the boiler, to take out flues once in six to twelve months, for the purpose of removing scale from both boiler and tubes. Railway engineers in Western States realize similar

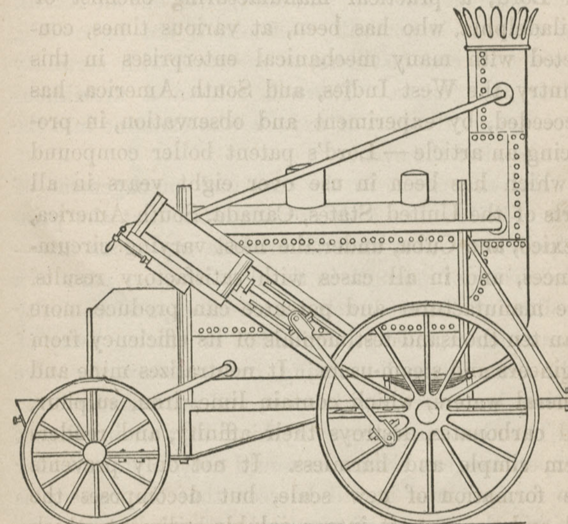
difficulties in a greater or less degree, according to location.

Mr. Ham, of the New York Central, stated that he can run with economy on the Eastern Division four years without taking out the flues; while on the Middle Division, on account of lime and scale, he has to take them out, on an average, every year and a half, and on the Western Division every two years. He finds it necessary, on the Middle Division, to put new sheets in the bottom of the cylinder part of the boiler on an average every five years; and with good water has only repaired that portion of the boiler once in eight to ten years. He knows nothing equal to pure water to keep boilers free from mud and scale.

At another meeting of the American Railway Master Mechanics' Association, the committee to whom was referred the subject of steam-boiler incrustation, after a series of very exhaustive experiments, reported that the only preventive against incrustation was the use of pure water in steam-boilers. It was also stated that the extra expense in one year, from impure water and incrustation, would amount to $75,000 for every hundred locomotives. The committee considered that to boil sufficient water to supply a locomotive for one year, running 31,000 miles, would require an extra expenditure of $236 for fuel; but they considered that that was the only reliable means for preventing incrustation and all manner of ruptures and leaks in boilers.

As before stated, what is needed to render efficient and permanent relief is an article that will attack the scale, render it porous, and destroy the affinity between it and the iron, without any injuries to the latter, and will hold the minerals and ingredients, which are passing in with the feed-water, in the form of slush or sludge, until they can be blown out. G. W. Lord, a practical manufacturing chemist of Philadelphia, who has been, at various times, connected with many mechanical enterprises in this country, the West Indies, and South America, has succeeded, by experiment and observation, in producing an article — Lord's patent boiler compound — which has been in use over eight years in all parts of the United States, Canada, South America, Mexico, and Cuba, under the most varying circumstances, and in all cases with satisfactory results. The manufacturer and patentee can produce more than ten thousand testimonials of its efficiency from engineers and steam-users. It neutralizes mine and mineral waters, which contain lime, iron, sulphur, and carbonates, destroys their affinity, and renders them simple and harmless. It not only prevents the formation of new scale, but decomposes the old and converts it into a soluble sediment, which may be blown out every day. It contains no acid which has any injurious effect on the iron of the boiler,— evidence of which may be found in the fact that the manufacturer, some years ago, filled several thousand vials with a solution of his compound, in which was placed a quantity of bright iron turn-

ings and small pieces of steel wire, which appear as bright as the day they were immersed in the solution, one of which will be sent to any one who feels incredulous on the subject. Lord's compound gives relief in all cases when used according to directions. Parties wishing to test its efficiency should address GEO. W. LORD, Philadelphia, Pa.



GEO. STEPHENSON'S LOCOMOTIVE, THE "ROCKET"—1829.

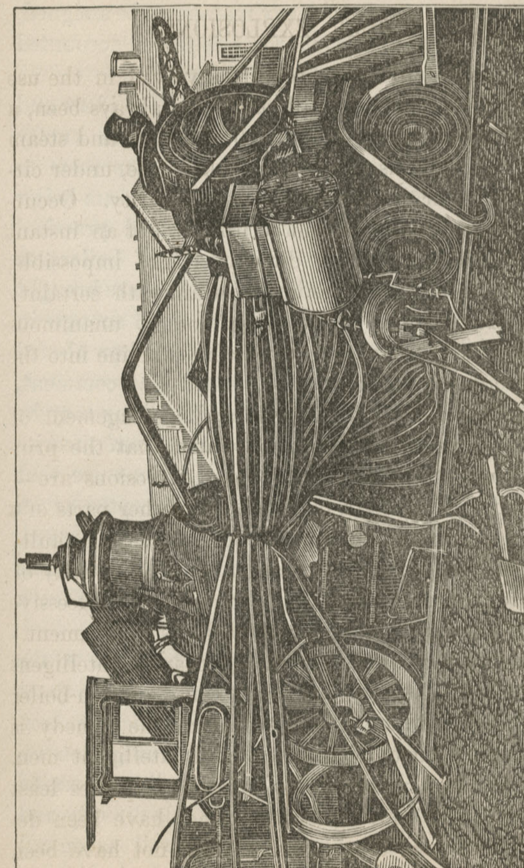
The above cut represents George Stephenson's locomotive "The Rocket," which won the prize at Manchester, 1829, and fully established the success of the locomotive.

BOILER EXPLOSIONS.

The risk of life and property involved in the use of the steam-boiler is still, as it has always been, a source of constant anxiety to the engineer and steam user. Explosions continually take place, under circumstances of the utmost apparent security. Occurring without warning, and occupying but an instant of time, it is generally difficult, if not impossible, except in rare instances, to ascertain with certainty their true cause. There is seldom a unanimous opinion on the part of experts who examine into the causes after the event.

But experience in the care and management of steam-boilers has fully demonstrated that the principal causes that tend to produce explosions are — deficiency of strength in the shell or other parts of a boiler, insufficient bracing, unequal expansion, faulty construction, leakage, oxidation or rusting away of the iron, internal grooving, over-pressure, excessive firing, ignorance, recklessness, and mismanagement.

The above includes everything that an intelligent experience has shown us would cause a steam-boiler to explode, and it will be seen that the remedy is within the control of practical and intelligent men. Of course boilers sometimes give out in places least expected, and show weaknesses, that have been developed by use, that perhaps could not have been discovered in any other way; and there may also be



The above cut represents the locomotive Charles Millard, which exploded while standing on the track at Watertown, N. Y., under a steam pressure of 110 lbs. to the square inch.

instances where no satisfactory reason can be assigned, but it is possible that even these could be accounted for, were all the circumstances known.

Though we are indebted to science for ideas and facts that have solved some of the most knotty problems in mechanics, still scientific men seem to be more in the dark on the subject of steam-boiler explosions than most of our experienced practical men engaged in the care or running of boilers, as their theories do not accord with facts that are brought to light in every-day practice. It is well enough in some cases to advance theories, no matter how absurd they may be, because they induce thought, comment, and experiment, by which at least something may be gained; but the evils likely to arise from theories advanced in the case of boiler explosions are that these scientific theories are apt to be accepted as an established fact before anything has been proved, because they are given to the public on occasions when every one is excited by, and anxious to learn the cause of, some terrible disaster.

The investigation of the causes which led to the explosion of the ferry-boat Westfield covered a great deal of paper, but its practical meaning might be condensed into a small space, as the investigation revealed the fact that the shell of that boiler concealed for years nearly every defect that leads directly and indirectly to disaster. On that, as well as on all former occasions of a like character, the scientific experts were on hand with the gas, electricity, decomposed steam, dissociation of water, concussive ebullition, and fatigue of metal theories. The fact that the engineer in charge did not know whether the steam-gauge and safety-valves on his boiler were in a serviceable condition or not; or that, according to Fairbairn's experiments, and all past and present experience in the strength of steam-boilers, he was carrying about twice the pressure that the boiler would stand with safety when new, did not seem worthy of the attention of the scientific experts. Of course it would be unscientific to attribute the cause of such a disaster to imperfections in construction, poor workmanship, scant bracing, cracked flanges, etc.

It is true we have commissioners appointed by the Government for the purpose of making experiments, and finding out, if possible, why boilers explode, but the results of such experiments never amount to anything, nor is any one better posted on boiler explosions after the experiment is over. The idea of building a steam-boiler and then bursting it for the purpose of showing how much strain it took to burst it, seems to be akin to knocking a man's brains out with a club for the purpose of showing the jury on the trial of a murder case how hard a blow it must have taken to kill the murdered man. Experiments on obsolete or especial types of boilers, or those made in the laboratory, will do little towards preventing the explosion of boilers, because the conditions under examination of that class of boilers is more difficult than that of any other, as they are of necessity complicated and difficult to enter; but, nevertheless, the American Master Mechanics' Association, a body of very talented and practical mechanics, have taken the subject of boiler explosions in hand at their yearly convention, and as they show by their discussions that they are no visionary theorists, but men of sound practical ideas, there cannot be any doubt but that their deliberations will elicit such information as will cause locomotive boiler explosions to be less frequent than they have been in the past. And as an evidence that they are fully alive to the best means for preventing such disasters, the more practical of them, at their last convention, declared that the first step to be taken to prevent boiler explosions is to secure good material for the boiler; next, good workmanship, and then care and intelligence in their use and management.

The number of locomotive boilers that exploded in the United States within the last six years amounted to 103, causing the loss of 151 lives, and property to the amount of several million dollars. Any class of men that, by their practical intelligence and example, will render such disasters less frequent, will confer a great boon on mankind.

ACCIDENTS.

Rules for the Course to be followed by the By-standers in case of Injury by Machinery, where Surgical Assistance cannot at once be obtained.

If there is bleeding, do not try to stop it by binding up the wound. *The current of the blood to the part must be checked.* To do this, find the artery by its beating; lay a firm and even compress or pad (made of cloth or rags rolled up, or a round stone

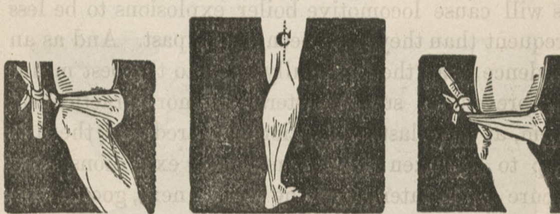


Fig. 1. Fig. 2. Fig. 3.

or a piece of wood well wrapped) *over the artery*, (see *Fig.* 1;) tie a handkerchief around the limb and compress; put a stick through the handkerchief and twist the latter up till it is *just tight enough to stop the bleeding;* then put one end of the stick under the handkerchief to prevent untwisting, *as in Fig.* 3.

The artery in the thigh runs along the inner side of the muscle in front, near the bone. A little above the knee it passes to the back of the bone. In injuries at or above the knee, apply the compress high up on the inner side of the thigh, at the point where the two thumbs meet at C, in *Fig.* 4, with the knot on the outer side of the thigh. When the leg is injured below the knee, apply the compress at the back of the thigh, just above the knee, at C, in *Fig.* 2, and the knot in front, as in *Figs.* 1 and 3.

The artery in the arm runs down the inner side of the large muscle in front, quite close to the bone. Lower down it gets farther forward toward the bend of the elbow. It is most easily found and compressed a little above the middle. (See *Fig.* 5.)

Fig. 4.

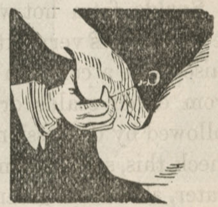


Fig. 5.

Care should be taken to examine the limb from time to time, and to lessen the compression if it becomes very cold or purple; tighten up the handkerchief again if the bleeding begins afresh.

In the case of shock, when the injured person lies pale, faint, cold, and sometimes insensible, with labored pulse and breathing, anything like excitement must be avoided, as it tends to exhaust the patient, who should be laid down with the head rather low. Much talking should be strictly avoided,

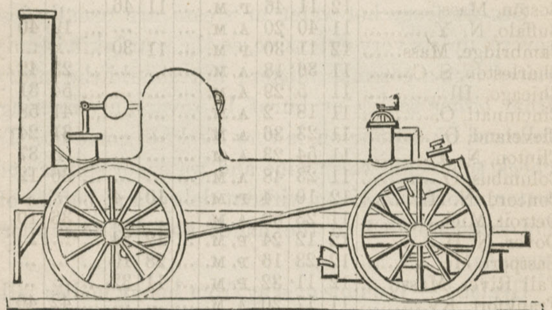
unless in words of encouragement. External warmth should be applied, and the person covered with blankets, and bottles of hot water or hot bricks applied to the feet and to the armpits.

Burns and Scalds.—Injuries of this kind are more dangerous when situated on the chest or body than when on the limbs. Burns are generally more severe than scalds, because the skin is more frequently destroyed, producing a slough or mortification of the part, which must separate and come away before the wound can be healed.

Scalds from hot water or steam are usually less severe, unless very extensive, as the scarf skin is only raised like a common blister; but should the injury from either scalds or burns be severe, a shivering, followed by depression, is very likely to come on. To check this, some warm wine and water, or spirits and water, should be given without delay, and bottles of hot water applied to the hands and feet to support warmth.

Bruises.—Wounds arising from heavy bodies falling on the person, or the person falling from a considerable height, require prompt treatment; but danger generally arises from the shock to the system, and until the arrival of medical aid all efforts should be directed to making the patient as comfortable as possible, by warm applications or poultices. Flannel made warm and applied to the skin, and in some cases cold water, is very refreshing. Stimulants should be avoided except in cases demanding their administration, but they are agents of great value in the treatment of that condition of collapse and faintness which very commonly occurs after severe injury.

In administering stimulants, the best practical rule is to give a small quantity at first and watch the effect; if the surface becomes warmer, the breathing deeper and more regular, and the pulse at the wrist more perceptible, then there can be no question as to the advantage of giving a little more.



THE DE WITT CLINTON—1831.

The first locomotive built in the United States that bore any resemblance to the modern locomotive. Diam. of cylinders, 5½ inches; stroke, 16 in.; diam. of drivers, 4½ feet. The boiler contains 32 copper tubes, 4 inches in diameter and 5 feet long. Weight of locomotive complete, 4 tons.

TABLE

SHOWING THE TIME AT 80 DIFFERENT PLACES, WHEN IT IS 12 O'CLOCK AT NEW YORK CITY; ALSO, COLUMN SHOWING DIFFERENCE OF TIME FROM NEW YORK.

New York City, 12 M.					Fast.			Slow.		
Places.	H.	M.	S.		H	M.	S.	H.	M.	S.
Albany, N. Y.	12	1	1	P. M.	...	1	1	...	...	...
Annapolis, Md	11	50	4	A. M.	...	...	...	...	9	56
Augusta, Me	12	16	40	P. M.	...	16	40	...	...	...
Baltimore, Md	11	49	33	A. M.	...	...	...	...	10	27
Bangor, Me	12	20	52	P. M.	...	20	52	...	...	...
Boston, Mass	12	11	46	P. M.	...	11	46	...	...	...
Buffalo, N. Y.	11	40	20	A. M.	...	...	...	...	19	40
Cambridge, Mass	12	11	30	P. M.	...	11	30	...	...	...
Charleston, S. C.	11	36	18	A. M.	...	...	...	..	23	42
Chicago, Ill	11	5	29	A. M.	...	...	...	...	54	31
Cincinnati, O.	11	18	2	A. M.	...	...	...	...	41	58
Cleveland, O.	11	23	36	A. M.	...	...	...	...	31	24
Clinton, N. Y.	11	54	23	A. M.	...	...	...	...	5	37
Columbus, O.	11	23	48	A. M.	...	...	...	...	36	12
Concord, N. H.	12	10	4	P. M.	...	10	4	...	...	...
Detroit, Mich	11	23	50	A. M.	...	...	...	...	36	10
Dover, N. H.	12	12	24	P. M.	...	12	24	...	...	...
Eastport, Me	12	23	16	P. M.	...	28	10	...	...	...
Fall River, Mass	12	11	32	P. M.	...	11	32	...	...	...
Frankfort, Ky	11	17	20	A. M.	...	...	...	...	42	40
Gloucester, Mass	12	13	21	P. M.	...	13	21	...	...	...
Greenwich, Eng	4	56	...	P. M.	4	56	...	...	...	...
Halifax, N. S.	12	41	33	P. M.	...	41	33	...	...	...
Hallowell, Me	12	16	40	P. M.	...	16	40	...	...	...
Harrisburg, Pa	11	48	40	A. M.	...	...	...	...	11	20
Hartford, Conn	12	5	17	P. M.	...	5	17	...	...	...
Havana, Cuba	11	26	29	A. M.	...	...	...	...	33	31
Key West, Fla	11	28	50	A. M.	...	...	...	...	31	10
Leavenworth, Kan.	10	37	14	A. M.	...	...	...	1	22	56
Lexington, Ky	11	18	48	A. M.	...	...	...	...	41	12
Liverpool, Eng	4	43	59	P. M.	4	43	59	...	...	...

DISTANCE BY RAILROAD BETWEEN IMPORTANT PLACES IN THE UNITED STATES.

From New York to

	Miles.
Albany	144
Baltimore, Md	184
Boston	236
Buffalo, via Hornellsville	423
Buffalo, via Albany	442
Charleston, S. C	788
Chicago, via Albany, Buffalo and Cleveland	980
Chicago, via Buffalo and Cleveland	1043
Chicago, via Erie Railway and Cleveland	957
Chicago, via Philadelphia and Pittsburg	935
Cincinnati, via Albany and Buffalo	880
Cincinnati, via Erie Railway and Dunkirk	857
Cincinnati, via Philadelphia and Pittsburg	807
Cleveland, via Albany and New York Central	625
Cleveland, via Erie Railway	602
Cleveland, via Philadelphia and Pennsylvania	580
Dunkirk	460
Indianapolis, via Albany, Buffalo and Cleveland	911
Indianapolis, via Erie Railway and Cleveland	888
Indianapolis, via Philadelphia and Pittsburg	838
Louisville, via Dunkirk	994
Louisville, via Philadelphia	946
Milwaukee, Wis., via Dunkirk and Chicago	1049
Mobile, Ala	1432
Montreal, Canada	403
Niagara Falls, via Erie Railway	438
Niagara Falls, via New York Central	447
Philadelphia	87
Quebec, Canada	582
Richmond, Va	355
Rock Island, Ill	1139
St. Louis, via Dunkirk and Chicago	1242
Washington, D. C	244

From Boston to

	Miles.
Albany	200
Augusta, Me	165
Baltimore	420
Buffalo	498
Charleston, S. C	1018
Chicago, via Canada	1013
Cincinnati, via Cleveland	936
Halifax, N. S	653
Montreal, Canada	322
New Orleans, La	1828
New York, via Hartford	236
Philadelphia	323
Portland, Me	105
Quebec, Canada	422
Richmond, Va	591
Savannah, Ga	1143
St. Louis, via Chicago	1298
Washington, D. C	460

From Philadelphia to

	Miles.
Baltimore	97
Boston	323
Buffalo	424
Charleston	789
Chicago	847
Cincinnati, via Pittsburg and Steubenville	663
Cleveland, via Pittsburg	492
Detroit, Mich	766
Elmira	275
Galena, Ill	1018
Harrisburg, Pa	106
Indianapolis, via Steubenville and Columbus	730
Louisville, via Steubenville and Cincinnati	796
Louisville, via Pittsburg and Ohio River	963
Milwaukee, via Cleveland	937
Mobile	1345
Montgomery, Ala	1148
New Orleans	1511
Niagara Falls	443
Pittsburg	353
Pottsville, Pa	93
Richmond, Va	268
Rochester, N. Y	373
Rock Island, via Chicago	1028
Savannah, Ga	901
St. Louis, via Cleveland and Chicago	1132
St. Louis, via Pittsburg and Indianapolis	1022
St. Louis, via Pittsburg and Cincinnati	1050
Toronto, via Catawissa and Niagara	497
Washington, D. C	137

From Baltimore to

	Miles.
Boston	420
Charleston, S. C	692
Chicago, via Wheeling and Cleveland	878
Cincinnati, via Wheeling and Central Ohio Railroad	629
Cincinnati, via Wheeling and Ohio River boat	763
Cleveland, via Baltimore and Ohio Railroad	523
Cleveland, via Pennsylvania Railroad	469
Cumberland, Md	178
Elmira, N. Y	247
Harper's Ferry	82
Jonesboro', Tenn	524
New York	184
Niagara Falls	415

From Baltimore to	Miles.
Philadelphia	97
Pittsburg, via Pennsylvania Railroad	330
Raleigh, N. C	342
Rock Island, via Chicago	1059
Staunton, Va	197
St. Louis, via Wheeling and Ohio and Mississippi Rivers	1459
Washington, D. C	40
Wheeling, via Baltimore and Ohio Railroad	380
Williamsport, Pa	169

From Washington, D. C., to	Miles.
Baltimore	40
Boston	460
Buffalo	442
Charleston, S. C	652
Chicago	864
Cincinnati, Ohio	509
Cleveland	509
Corralles, Oregon (Overland Route)	3485
Detroit, Mich	684
Galveston, Texas	1800
Halifax, N. S	1113
Memphis, Tenn	1476
Mexico, City of Mexico	2400
Montreal, Canada	627
New Orleans, La	1365
New York	224
Philadelphia	137
Quebec, Canada	772
Salt Lake City	2672
San Francisco (Overland)	3000
Santa Fé, New Mexico	2192
St. Louis, Mo	1040
St. Paul, Minn	1345
Toronto, Canada	623

OVERLAND ROUTE.

Atchison to	
Fort Kearney	260
Denver, Colorado	650
North Platte	876
Green River	1053
Great Salt Lake City, Utah	1250
Bear River	1340
Boisée City	1649
Virginia City	1733
Helena	1853
Sierra Nevada (Summit)	2085
Sacramento City	2225
San Francisco	2365

St. Louis to	
Fort Kearney	598
Fort Laramie	1058
Red Buttes	1215
Fort Bridger	1493
Bear River	1528
Fort Hall	1684
Fort Boisée	2001
Fort Walla-Walla	2229
Fort Vancouver	2416
Oregon City	2446

DISTANCES FROM PHILADELPHIA TO CITIES AND TOWNS IN THE UNITED STATES BY THE SHORTEST ROUTES.

	Miles.
Albany, N. Y	232
Absecom, N. J	52
Allentown, Pa	71
Alliance, Ohio	449
Atlantic City, N. J	59
Altoona, Pa	238
Augusta, Ga	742
Baltimore, Md	97
Bangor, Me	578
Bellefonte, Pa	250
Bethlehem, Pa	54
Beverly, N. J	13
Boonsburg, Pa	149
Bordentown, N. J	27
Boston, Mass	323
Bridgeton, N. J	37
Bristol, Pa	17
Bristol, Va	620
Brooklyn, N. Y	89
Buffalo, N. Y	424
Burlington, N. J	19
Burlington, Iowa	1050
Camden, N. J	1
Cape May City, N. J	84
Carlisle, Pa	124
Catawissa, Pa	145
Catskill (Landing) N. Y	199
Charleston, S. C	563
Chambersburg, Pa	158
Chattanooga, Tenn	760
Chester, Pa	14
Cheyenne, Dakota	1824
Chicago, Ill	823
Cincinnati, Ohio	668
Claymont, Del	20
Clearfield, Pa	264
Cleveland, Ohio	505
Coatesville, Pa	40
Columbia, Pa	80
Columbus, Ohio	584
Corning, N. Y	292
Corry, Pa	413
Cresson, Pa	253
Crestline, Ohio	544
Crisfield, Md	163
Cumberland, Md	276
Danville, Pa	154
Davenport, Iowa	1006
Delanco, N. J	12
Delaware Water Gap, Pa	100
Detroit, Mich	675
Des Moines, Iowa	1180
Dover, Del	76
Downingtown, Pa	33
Doylestown, Pa	32
Dunkirk, N. Y	461
Eagle, Pa	17
Easton, Pa	66
Ebensburg, Pa	264
Egg Harbor, N. J	41
Elizabeth, N. J	73
Ellicott's Mills, Md	113

From Philadelphia to	Miles.
Elmira, N. Y	275
Elkton, Md	46
Erie, Pa	451
Flemington, N. J	58
Florence, N. J	23
Fort Harker, Kan	1499
Fort Riley, Kan	1414
Fort Wayne, Ind	675
Franklin, Pa., via Pittsburg	480
Frederick, Md	160
Fredericksburg, Va	208
Freehold, N. J	59
Galveston, Texas	1734
Gettysburg, (via Columbia, Pa.)	122
Girard, Pa	113
Glassboro, N. J	18
Grafton, Va	377
Greensburg, Pa	324
Gwynedd, Pa	18
Haddonfield, N. J	7
Hagerstown, Md	180
Hammonton, N. J	30
Hamilton, Canada	489
Harrington, Del	92
Harrisburg, Pa	106
Harper's Ferry, Va	179
Hartford, Conn	198
Havre de Grace, Md	62
Hightstown, N. J	41
Hollidaysburg, Pa	246
Hornellsville, N. Y	333
Huntingdon, Pa	204
Indiana, Pa	320

From Philadelphia to	Miles.
Indianapolis, Ind	736
Jackson, Miss	1344
Jamesburg, N. J	48
Jefferson City, Mo	1125
Jersey City, N. J	87
Johnstown, Pa	277
Kane, Pa	356
Kansas City, Mo	1280
Knoxville, Tenn	740
Lambertville, N. J	46
Lancaster, Pa	69
Laramie, Dakota	1886
Lawrence, Kan	1313
Leavenworth, Kan	1307
Lebanon, Pa	86
Lewistown, Pa	167
Linwood, Pa	18
Little Rock, Ark	1300
Lockhaven, Pa	228
Long Branch, N. J	82
Louisville, Ky	775
Lowell, Mass	358
Lynchburg, Va	316
Lynn, Mass	343
Madison, Wis	961
Mahanoy, Pa	117
Martinsburg, Va	198
Mauch Chunk, Pa	87
Media, Pa	14
Meadville, Pa	444
Memphis, Tenn	1152
Middletown, Pa	97
Milford, N. J	65
Millville, N. J	40
Milton, Pa	176

From Philadelphia to	Miles.
Milwaukee, Wis	908
Mobile, Ala	1472
Morgan's Corner, Pa	14
Montgomery, Ala	1037
Moorestown, N. J	10
Morristown, N. J	118
Morrisville, Pa	26
Mount Holly, N. J	18
Mount Joy, Pa	82
Nashville, Tenn	960
Natrona, Pa	378
Newark, Del	40
Newark, N. J	79
New Brunswick, N. J	56
Newburyport, Mass	368
Newburg, N. Y	148
New Castle, Del	34
New Haven, Conn	160
New London, Conn	160
New Orleans, La	1527
Newport, R. I. (rail and boat)	251
New York City	88
Niagara Falls, N. Y	446
Northumberland, Pa	163
Norristown, Pa	17
Ogden, Utah	2346
Oil City, Pa	440
Omaha, Nebraska	1316
Paoli, Pa	20
Parkersburg, Va	481
Parkersburg, Pa	45
Paterson, N. J	104
Pemberton, N. J	24
Pensacola, Fla	1106

From Philadelphia to	Miles.
Perryville, Md	61
Petersburg, Va	290
Phillipsburg, N. J	81
Philipsburg, Pa	227
Phœnixville, Pa	28
Pittsburg, Pa	355
Pittstown, Pa	151
Pittson, N. J	26
Port Clinton, Pa	78
Portland, Me	440
Portsmouth, N. H	384
Pottstown, Pa	40
Pottsville, Pa	98
Poughkeepsie, N. Y	163
Princess Anne, Md	144
Princeton, N. J	40
Providence, R. I	272
Promontory, Utah	2400
Quakake, Pa	106
Quakertown, Pa	38
Rahway, N. J	68
Raleigh, N. C	451
Reading, Pa	58
Richmond, Va	268
Ridgeway, Pa	332
Riverton, N. J	7
Rochester, N. Y., via Williamsport, Pa	373
Rochester, Pa	381
Rupert, Pa	147
Sacramento, Cal	3090
Salt Lake City	2369
St. George's, Del	44
St. Louis, Mo	998
St. Mary's, Pa	323

From Philadelphia to	Miles.	From Philadelphia to	Miles.
St. Paul, Minn	1302	Toronto, Canada	528
Salem, Mass	348	Trenton, N. J	28
Salem, N. J	43	Troy, N. Y	238
Salisbury, Md	131	Tullytown, Pa	21
San Francisco, Cal.	3228	Tunkhannock, Pa	176
Saratoga, N. Y	264	Tyrone, Pa	524
Savannah, Ga	879	Uintah (Salt Lake)	2340
Schuylkill Haven, Pa	89	Valley Forge, Pa	24
Scranton, Pa	164	Vicksburg, Miss	1388
Seaford, Del	112	Vincennes, Ind	716
Sheridan, Kan	1685	Vineland, N. J	35
Sing Sing, N. Y	120	Warren, Pa	385
Smyrna, Del	66	Washington, D. C	138
South Amboy, N. J	63	Waterford, N. J	23
Springfield, Mass	224	Weldon, N. C	354
Steamboat, Pa	27	Westchester, Pa	27
Stroudsburg, Pa	102	Wheeling, Va	424
Sunbury, Pa	163	Whitehall, Pa	11
Suspension Bridge, N. Y.	448	White Haven, Pa.	110
Syracuse, N. Y	380	Wilkesbarre, Pa	142
Swedesboro, N. J	18	Williamsport, Pa	197
Tacony, Pa	6	Wilmington, Del	28
Tamaqua, Pa	98	Wilmington, N. C	516
Titusville, Pa	458	Woodbury, N. J	8

Number of Miles of Railroad in the World in 1873.—The whole number of miles of railroad in the world at the close of 1873, was about 167,500, or nearly seven times the circumference of the earth. North America, 86,000 miles; Europe and entire Eastern hemisphere, 79,000; South America, 2,500, all of which were constructed at a cost of $6,400,000,000.

VOCABULARY OF TECHNICAL TERMS AS APPLIED TO THE DIFFERENT PARTS OF LOCOMOTIVES.

Air Chamber.—An air-tight vessel attached to the feed-pump, for the purpose of cushioning the pump and lessening the jar caused by the action of the plunger and the pressure in the boiler.

Apron.—The sheet-iron plate that covers the space between the engine and tender.

Arch Pipes.—The steam-pipes which connect the double cone with the cylinders.

Ash Pan.—A box or tray beneath the furnace to catch the falling ashes and cinders.

Axles.—The revolving shafts to which the wheels of locomotives and cars are attached.

Back Dome.—The dome in which the dry-pipe is placed.

Back Furnace Brace.—A brace that runs from the back of the furnace to the end of the frames.

Bell Yoke.—A cast-iron yoke on top of the boiler, in which the bell swings.

Bissel Truck.—A truck especially designed to relieve the lateral rigidity in locomotives and enable them to pass curves with ease.

Blast Pipes.—Two pipes inserted in the exhaust ports, with their upper ends contracted, for the purpose of exciting an artificial draft.

Blow-off Cocks.—A cock at the bottom of the fire-box through which to empty the boiler.

Blower Pipe.—A pipe in the smoke-box connected with the blower-cock in the cab to blow steam through, for the purpose of producing a draft when the engine is not in motion.

Boiler. — The source of all power where steam is used as a motor. The vessel in which the steam is generated.

Bonnet. — A wire cap or netting surmounting the chimney, to keep down the sparks and cinders.

Boxes.—The bearings resting on the journals of locomotive and car axles.

Brackets.—The braces which support the head-lights on the front end of locomotives.

Brasses. — A term applied to the boxes on the cross-heads and crank-pins of locomotives.

Brake.—A drag applied, by moving of rods and levers, to the wheels of railway cars, for the purpose of checking their velocity

Brick Arch.--A brick slab placed across the front end of the furnace, directly over the fire, for the purpose of holding the smoke and gases in contact with the fire until they become thoroughly mixed.

Bumpers. —Timbers bolted to the frame on the front end of engines and rear end of tenders.

Bumper Blocks. — Pieces of timber bolted to the bumpers for the purpose of receiving the jar when the cars strike.

Bumper Sheet.—A sheet placed on the front end of the frame to cover the space between the bumper and the cylinders.

Cab. — A house for the engineer and fireman on the back end of the boiler of the locomotive.

Cab Handles. — Handles fastened on the cab to assist the engineer and fireman in getting on or off the engine.

Cellars. — Chambers in the jaws of the boxes, to hold oil for the purpose of lubricating the journals.

Cellar Bolts. — The bolts which hold the cellars up to the journals.

Centre Casting.—The casting that forms the connection between the truck-bolster and the front end of the boiler.

Check Valve. — A valve connected with the boiler to prevent the back pressure in the boiler from interfering with the action of the pump.

Check Chamber. — A chamber attached to the waist of the boiler, through which the water passes from the connecting pipe to the boiler.

Connecting Pipe.—The water-pipe that connects the pump with the check-valve.

Connecting or Main Rods.—The rods that communicate the pressure on the pistons to the crank-pins of the main driving-wheels.

Counter-balances. — Large blocks of iron, cast or secured to two or more arms of each driving-wheel, opposite the crank-pin, for the purpose of balancing the weight of the parallel and main rods and steadying the motion of the engine.

Cow-Catcher.— See PILOT.

Crank Pins. — The pins that convert the rectilineal motion of the pistons to the rotary motion of the driving-wheels.

Cross Heads. — Blocks moving in guides, having the end of the piston-rods secured within them at one end, and pins to attach the connecting-rods at the other.

Cross-Head Pins. — The pins or wrists in the cross-heads to which the main rods are attached.

Crown Bars.—Bars on the upper side of the crown-sheet in the water space, with their ends resting on the edges of the furnace-sheet, for the purpose of strengthening the crown-sheet.

Crown-Bar Braces.—Braces attached to the crown-bars and to the top shell of the boiler, to give additional strength to the crown-sheet and the top of the boiler.

Crown Sheet.—The top sheet of the furnace directly over the fire, to which the crown-bars are attached.

Cut Off.—See SLIDE VALVE.

Cylinders.—Two steam-tight tubes attached to the front end of the boiler at the smoke-box, in which the pistons move, through which the mechanical effects of the steam are transmitted to the cranks by means of steam-tight pistons.

Cylinder Cocks.—Small cocks on the lower side of the cylinders, through which the condensed water escapes.

Cylinder Heads.—The front and back head of the cylinders, the latter containing the stuffing-boxes, through which the piston-rods move.

Dampers.—Doors in the front and rear end of the ash-pan to regulate the quantity of air admitted to the furnace.

Damper Handle.—A handle passing through the foot-plate to open or close the dampers.

Dashers.—Sheet-iron plates attached to the inside shell of the boiler opposite the pump-check, for the purpose of preventing the cold water from striking the tubes.

Deflector.—An arrangement used in the furnaces of locomotives for the purpose of mixing the air and gases, and causing the latter to ignite and render the combustion of the fuel more perfect.

Dome.—The elevated chamber on the top of the boiler from which the steam is taken to the cylinders.

Dome Bodies.—The sheet-iron jacket that surrounds the domes of locomotives outside of the wooden lagging.

Dome Stays.—Braces connected with the crown-bars at one end, and the dome at the other, for the purpose of strengthening the dome and the crown-sheet.

Dome Top.—A covering to which the safety-valves and whistle-stand are attached.

Double Cones.—The steam-tight joint that connects the steam-pipe and arch-pipes with the flue-sheet in the smoke-box.

Double Truck.—A truck with two pair of wheels.

Drag Iron.—The bar that connects the engine with the tender by means of a drag-pin.

Drag Pin.—The pin by which the drag-iron is attached to a yoke under the foot-plate.

Draw Bar.—A bar on front of the pilot for the purpose of connecting the locomotive with cars or with another engine.

Driving Saddle.—A yoke or stand which straddles the frame, and on which the driving-springs rest.

Driving Wheels.—The wheels through which the locomotive obtains its power, by their adhesion to the rails.

Eccentric.—Cams on the main axles of the driving-wheels, through which the slide-valves receive their motion.

Eccentric Straps.—The straps that encircle the eccentrics, and to which the eccentric rods are attached.

Eccentric Rods.—Rods having one end attached to the eccentric strap and the other end to the link.

Equalizing Levers.—Bars suspended by their centre beneath the frame, and connected at each end to the springs of the drivers to distribute any shock or jolt received by the wheels.

Equalizing Springs.—Springs used on the reverse shaft to equalize the weight of the links. They are either spiral or elliptic, according to circumstances.

Exhaust Cavity in Valves.—A cavity in the valve-face to allow the steam to escape from the cylinders, over the bars or bridges, to the exhaust-pots.

Exhaust Nozzles.—Nozzles inserted in the exhaust pots, for the purpose of decreasing the openings in order to excite the draft in the furnace.

Exhaust Ports.—Openings in the middle of the valve-seats, through which the exhaust steam escapes from the cylinders to the exhaust-pots.

Exhaust Pots.—Cone-shaped pipes attached to the exhaust cavities of the cylinders in the smoke-box.

Expansion Clamps.—Clamps attached to the fire-box under the main frame, for the purpose of holding the frame against the liners.

Expansion Clamps.—Clamps bolted over the main frames and furnace pads to allow for the expansion of the boiler.

Expansion Joints.—A joint on the throttle-pipe to allow for expansion.

Feed Pipes.—Pipes or hose connected at one end with the tank and at the other with the receiving chamber of the pump, through which the water passes from the tank to the pump.

Feed Pipe Hangers.—Hangers bolted to the bottom of the frame, for the purpose of supporting the feed-pipes.

Feed Water Cocks.—Cocks in the ends of the pipe to regulate the supply of water to the pumps.

Feed Water Shafts.—Upright shafts passing through the foot-plate to the feed-water cocks, and operated by means of cranks.

Fire Box.—The furnace of the locomotive; the chamber in which the fuel is consumed.

Fire Door.—A door on the back end of the boiler through which the fuel is introduced into the furnace.

Foaming.—An artificial excitement or ebullition of the water in the boiler when the water becomes foul or greasy.

Follower Bolts.—The bolts that secure the follower plates to the piston-heads.

Follower Plates.—The plates that cover the spring-packing on the front end of the piston-heads.

Foot Board.—A board at the back end of the boiler on which the engineer stands.

Foot Plate.—A cast-iron plate bolted to the back end of the frame in front of the fire-door, and to which the drag-iron is attached by means of the drag-pin.

Frame.—Parallel pieces to which the cylinders, cross-ties, and all the main parts of the locomotive are attached.

Frame Braces.—Horizontal braces between the pedestals.

Front Door.—A door on the front end of the boiler inclosing the smoke-box.

Front Rail.—The front attachment of the frame extending from the front bumper back to the front drivers.

Frost Cocks.—Cocks to admit steam from the boiler to the feed-pipes, to prevent freezing in cold weather.

Frost Plugs.—Plugs screwed into the pump-chambers and pump-cages, to allow the water to escape from the pump-chamber and prevent freezing.

Fulcrum. — The prop, support, or fixed point upon which the levers of the safety-valves are sustained, and on which they are supposed to turn freely.

Fulcrum of Equalizing Beams. — Tongues on the frame between the driving-wheels on which the equalizing beams vibrate, by which the weight of the engine is equalized on the drivers.

Furnace Pads.—Knees bolted on the shell of the fire-box, by which the weight of the boiler rests on the frame.

Furnace Rings. — The wrought-iron ring that forms the connection between the outside and inside sheets in the water space at the bottom of the furnace.

Fusible Plug.—A plug sometimes used in the crown-sheets of locomotive boilers for the purpose of giving warning in case the water in the boiler should become dangerously low. The metal of the fusible plug consists of 8 parts of bismuth, 5 of lead, and 3 of tin; it melts at the heat of boiling water, or 212° Fah.

Gasket. — A gum packing for the man-hole or hand-holes of boilers.

Gauge Cocks. — Cocks at different levels on the back end of the boiler, to ascertain the height of the water in the boiler.

Gib.—The fixed wedge for taking up the wear in boxes on cross-heads and crank-pins.

Gland. — A bushing to secure the packing in stuffing-boxes.

Glass Gauge. — A glass tube on the back end of the boiler, connected with the steam- and water-valves, to indicate the height of the water.

Goose Neck. — A brass or cast-iron neck connecting the front end of the feed-pipe to the lower chamber of the pump.

Grate.—The parallel bars on which the fuel is burned when soft coal or wood is used.

Gromnet. — A ring of hemp used as a packing.

Guide.—A sleeve on the front end of the steam-chest, in which the end of the valve-rods move.

Guide.—The piece to which the throttle-valve lever is made fast, to prevent slipping when the engine is in motion.

Guide Bars. — The parallel pieces between which the cross-hedges move.

Guide Bearer. — A bar or brace bolted across the frames, to which the guide-blocks are attached.

Guide Blocks. — The blocks on the back head of the cylinder and on the guide-bearer, to which the guide-bars are attached.

Guide Brace. — A brace attached to the guide-bearer at one end, and the boiler at the other, for the purpose of supporting the guide-bearer.

Hand Holes. — Holes in the outside shell of the furnace near the ring, through which to remove the deposits of rust or dirt that may accumulate in the water-legs of the furnace.

Hand Rail.—A rail running lengthways of the boiler, supported by studs, used as a safeguard to the engineer in getting on or off the foot-board when the engine is in motion.

Head Light. — A light used on the front end of locomotives.

Heater Cocks. — Cocks attached to the boiler in the cab for the purpose of blowing steam through the feed-pipes to the pumps in cold weather.

Heater Pipes. — Pipes connecting heater cocks with feed-water pipes.

Hollow Stays. — Hollow stay-bolts passing through the outside and inside sheets of the furnace near the crown-sheets, to admit air to the furnace for the purpose of increasing the combustion of the fuel.

Horns. — Knees on the top side of the frame, back of the front bumper.

House Boards. — Boards on the sides of the boiler attached to the house-brackets, on which the house rests.

House Brackets. — Cast-iron brackets attached to the back bumper of the engine, and on which the house-boards rest.

House Knees.—Wrought-iron knees used in attaching the house-boards to the shell of the boiler.

Induction Ports. — The passages in the valve-seat through which the steam enters the cylinders.

Injector. — An instrument used in supplying boilers with feed water. See INJECTOR.

Jacket. — A covering for steam cylinders.

Jam Nuts. — Nuts used for setting out the spring-packing in piston-heads.

Jam Wrenches. — Wrenches used for locking the nuts of the spring-packing on piston-heads.

Jaw.—A stand secured to the frames of railway cars to hold the boxes in which the journals of the axles revolve.

Journals.—That part of the axles on which the boxes rest.

Keys. — The wedges for tightening the straps which hold the brasses at the ends of the connecting-rods.

Key Way. — A slot in a shaft to receive the key where two pieces of machinery are connected by means of a key or keys.

King Pin.—A pin passing through the centre casting and the truck centre, for the purpose of preventing the latter from becoming detached from the former.

Knuckle Joints. — Joints on the valve-rods to allow them to vibrate freely with the radius of the rocker-arm.

Lagging. — A wooden sheathing placed round the boiler and cylinders of locomotives, for the purpose of excluding the atmosphere and preventing condensation.

Lap.—The distance which the slide-valves overlap the receiving ports when in the middle of their travel.

Lead.—The amount of opening the slide-valves have on the steam end when the pistons commence the stroke or the cranks are on the dead centre.

Lifting Links.— The links which connect the lifting-arms of the reverse shaft to the saddle-pins of the links, by means of which the links are raised and lowered.

Lifting Pipe, Clearance Pipe, or Petticoat Pipe. — A funnel-shaped pipe over the exhaust-pots in the smoke-box, that can be raised or lowered to equalize the draft in the tubes.

Liners or Frame Liners. — Pieces of iron placed between the frames and the furnace to keep the boiler in its proper position between the frames.

Link. — A variable radius expansion gear used on locomotives for the movement of the steam-valves.

Link Block. — A block working between the jaws of the link and connected with the upper arm of the rocker.

Lubricator. — The valve or globe through which the oil or tallow is admitted to the cylinders, either from the steam-chest or cab.

Main Frames. — The frame that runs from the front end of the drivers to the back end of the engine.

Mud Cock.—A cock in the mud-drum through which to discharge the mud from the drum.

Mud Drums. — A small cylinder attached to the under side of the waist of the boiler, to receive the deposits carried into the boiler by the feed water.

Mud Holes. — Openings in the back end of the fire-box, generally closed by brass plugs, through which to remove the mud from the lower water space.

Offsets.—Recesses in the outside shell of the fire-box to allow the spring-saddles room between the fire-box and frame.

Packing. — A substance used to make a steam-tight joint around the piston- and valve-rods.

Packing Hook. — A steel hook used for removing the old packing from the stuffing-boxes when it becomes necessary to repack the engine.

Packing Rings. —The rings on the piston-head that form the steam-tight joint in the cylinder.

Packing Stick. — A small stick used to drive the packing into the stuffing-boxes.

Pedestal Caps. — Caps on the bottom of driving and truck pedestals.

Pet Cock. — A small cock communicating with the valve chamber of the pump to show whether the pump is working or not.

Pilot. — A fender bolted on the front bumper to remove obstructions from the track.

Pilot Brace. — A brace running from the heel of the pilot to the front bumper.

Pin Plate. — A plate on the link to which the lifting-arm is attached.

Piston Heads.—Cast-iron heads attached to the piston-rods, on which the rings are fitted that form the steam-tight joint in the cylinders.

Piston Rod. — A rod keyed at one end to the piston-head, and at the other end to the cross-heads.

Pockets. — Recesses in the top of the driving and truck-boxes, in which the driving-saddles and equalizing beams rest.

Poney Truck. — A truck with one pair of wheels.

Priming. — Water carried over with the steam from the throttle-pipe to the cylinders.

Pulling Pin. — A pin in the foot-plate to which the drag-iron is attached.

Pump Cages. — Brass chambers between the pump-barrel and air-vessel, in which the valves are placed.

Quadrant. — A slotted segment in the cab, which holds the reverse lever in the right position by means of the reverse latch.

Quadrant. — A ratchet segment in the cab by which the variable exhaust is regulated.

Radius Bar. — An angle bar attached to the back end of the truck frame and to the radius bar cross-tie by means of a pin.

Radius Bar Cross-tie.—A bar slotted across the frame as a brace for the radius bar.

Reach Rod. — A rod connecting the reverse lever with the reverse arm of the reverse shaft.

Receiving Ports. — The openings in the valve-seat through which the steam passes from the steam-chests to the cylinders.

Reverse Latch.— A tongue fitted to notches in the quadrant, by which the reversing lever is held in position.

Reverse Shaft. — A shaft running parallel with the driving-axles at the top side of the frame, by means of which the links are raised or lowered.

Reversing Lever.—A lever in reach of the engineer, by which the motion of the engine can be changed and the travel of the valves increased or decreased.

Rockers. — Double cranks, connected with the link-blocks at one end and the valve-rods at the other, by which the valves receive their motion through the intervention of the eccentrics and links.

Rocker Boxes.— Boxes attached to the frames in which the rocker-shafts vibrate.

Saddle Pin.— A pin on the back of the saddle-plate, to which the lifting link is attached, and by means of which the main link is raised or lowered.

Saddle Plate.— The plate that forms the base of the saddle-pin on the link.

Safe Ends. — Copper ferrules brazed to the end of the iron tubes to form the lip on the tube-sheets.

Safety Chains. — Chains attached to the front bumper and the front end of the truck frame, for the purpose of preventing the truck from swinging round and breaking the links in case the locomotive should run off the track.

Safety Hooks. — Hooks bolted to the back bumper of the engine ; the safety chains of the tender are attached.

Safety Valves. — Valves on the dome-cover to discharge the surplus steam from the boiler.

Sand Box.— A cylindrical box or dome attached to the top of the boiler, for carrying sand for the engine.

Sand Box Rod.—A rod communicating with the sand-box in the cab, by which the sand-valves are moved.

Sand Pipes. — Pipes communicating with the sand-box, through which the sand passes to the rails in front of the drivers, to prevent the wheels from slipping when the rails are damp or greasy.

Scroll Irons. — Iron bands placed round the ends of the front bumper under the bumper-sheet.

Shell. — The outside sheets of the boiler.

Slide Valves. — Slide-valves are the valves which control the admission and escape of steam to and from the cylinders.

Smoke Box. — A chamber at the forward end of the boiler which contains the arch-pipes, lifting-pipes, exhaust-pots, and blower-pipes, and through which the smoke escapes from the furnace to the smoke-stack.

Smoke Box Ring. — A wrought-iron ring in the front end of the smoke-box, to which the frame of the front door is attached.

Smoke Box Brace — A brace running from the smoke-box to the frame back of the horn.

Smoke Stack. — The chimney through which the smoke escapes from the smoke-box.

Smoke Stack Base. — A saddle casting on the smoke-arch, to which the lower end of the smoke-stack is attached.

Spark Arrester. — A wire netting or screen in the stack to retain the sparks.

Springs. — Combinations of steel-plates connected at their centre by bands, and at the ends to the equalizing beams, for the purpose of lessening the jar on the engine produced by the inequality of the track.

Spring Balances. — Spring attachments in the cab connected at one end with the safety-valve levers, and at the other end with the top sheet of the boiler.

Spring Hangers.—The pieces that connect the end of the springs with the equalizing beams.

Spring Saddles or Spring Staples.—Yokes that straddle the frames and form a support for the springs on the top of the driving-boxes.

Stack Cone.—A casting used in the smoke-stack for the purpose of retarding the passage of the sparks as they escape from the furnace to the open air.

Steam Chests.—Boxes on the top of the cylinders containing the slide-valves, from which the steam is admitted to the cylinders.

Steam Gauge.—A gauge on the back end of the boiler, in the cab, to indicate the pressure of steam per square inch on the boiler.

Steam Pipes.—The pipes through which the steam passes from the dome to the arch-pipes in the smoke-box.

Stop Cocks.—Cocks on the water-pipes between the tender and pumps.

Stop Valves.—Valves used for different purposes in connection with the locomotive.

Straps.—The pieces that secure the brasses on the cross-head pins and wrists of the main drivers.

Stroke.—Half the distance travelled by the pistons at each revolution of the main drivers.

Stub Ends.—The ends of the main rods that butt against the boxes on the cross-heads and wrist-pins.

Stuffing Boxes.—Chambers in the back head of the cylinders and steam-chests, through which the piston-rods and valve-rods move.

Supply Ports.—Openings in the steam-chests through which the steam enters from the arch-pipes.

Swing Bolster.—A swinging bolster in the centre of the truck, on which the forward end of the engine rests, and which allows the locomotive to round sharp curves with ease.

Tender.—A carriage attached to the back end of the locomotive, for the purpose of carrying water and fuel.

Thimble.—An iron ring or bushing used for stopping leaks in the tubes of locomotive boilers.

Throttle Lever.—The lever by which the throttle-valve is opened and closed.

Throttle Pipe.—A vertical pipe having its lower end connected to the steam-pipe, and its upper end sustained by braces in the dome.

Throttle Valve.—A balance valve in the throttle-pipe, through which the steam is admitted to the steam-pipe.

Tires.—Wrought-iron or steel bands surrounding the driving-wheels of locomotives.

Trailing Wheels.—A pair of small wheels placed behind the drivers in cases where but one pair of driving-wheels is used.

Truck.—The frame, wheels, and springs on which the front of the locomotive rests.

Truss Rods.—Braces used for strengthening the truck.

Tubes.--The iron or copper flues through which the smoke escapes from the furnace to the smoke-box.

Tube Sheets.—The sheets in which the tubes are inserted.

Valves.—See SLIDE AND STOP VALVES.

Valve Yokes.—Wrought-iron bands surrounding the valves in the steam-chests, to which the valve-rods are attached.

Variables Exhaust.—An arrangement by which the opening in the exhaust nozzles can be contracted for the purpose of exciting the draft in the furnace.

Waist.—The cylindrical part of a locomotive boiler.

Waist Sheet.—A sheet of wrought-iron bolted to the waist of the boiler by angle iron, to which the guide-braces, guide-bearers, and cross-ties are attached.

Water Tubes.—Horizontal tubes used as grate-bars in the furnaces of anthracite coal burners.

Water Tables.—A hollow table or apron riveted to the front end of the furnace and communicating with the water space, for the purpose of changing the current of the air and gases, and rendering the fuel more combustible.

Wheel Covers.—A covering on the drivers and truck-wheels to prevent the machinery from being injured by the mud and sand.

Whistle.—A bell or gong used to give warning and indicate the approach of the locomotive.

Whistle Lever.—A lever attached to the whistle-base, to open the whistle-valves.

INDEX.

Absolute motion, 264.
Accelerated motion, 264.
Acceleration, 260.
Accidents, rules to be followed in case of, 285.
Adhesion, 260.
Air, 33.
  and fuel, mixture of, 65.
  expansion of, etc., table showing, 37.
  pressure of, 34, 35.
  resistance to motion caused by, 38.
Angle of friction, 260.
Angular motion, 264.
Animal strength, 260.
Anthracite coal, 66.
Areas of circles, tables of, 247, 248, 267, 271.
Ash-pans, 216.
Atomic or molecular force of heat, 59.
Attraction, 261.
Axles, 260.
  driving, brasses for, 159.

Balanced slide-valve, 145.
Baldwin anthracite coal-burning locomotive, 100.
Bituminous coal, 70.
Boiler flues, rule for finding safe external pressure on, 185.
Boiler pressures, tables of, 186, 191.
Boilers and boiler materials, definitions as applied to, 186.
  incrustation in, 272.
  rule for finding safe working pressure of, 183.
  locomotive, 163.
  locomotive, evaporative power of, 170.
  locomotive, heating surface in, 172.
  locomotive, heating surface to grate surface in, 174.
  locomotive, instructions for care and management of, 222.
  locomotive, machine and hand-riveting for, 179.
  locomotive, proportions of, 167.
  locomotive, rule for finding heating surface in, 174.
  locomotive, rule for finding heating surface in tubes of, 175.
  locomotive, steam room in, 172.
  locomotive, straight, 162, 176.
  locomotive, wagon-top, 167, 168.
  locomotive, water space in, 172.
  stationary, 175.
  steel, rule for finding safe working pressure of, 184.
Boiling point of water, 29.
Brasses for driving-axles, 159.
Bridges, 133.

Bruises, 287.
Burns, 287.

Caloric, 51.
conductors and non-conductors of, 51.
latent, 52.
radiation of, 51.
reflection of, 51.
sensible, 52.
Carbon, 77.
Carburetted hydrogen, 77.
Cast-iron, table showing tensile strength of, 257.
Centre of gravity, 262.
of oscillation, 264.
of percussion, 265.
Central or centrifugal force, 261.
Centripetal force, 261.
Chemical combinations accompanied by production of heat, 363.
equivalents, 64.
Circle, diameters, circumferences, and areas of, 247.
mensuration of, 242.
Circumferences of circles, table of, 247, 248.
Clearance-pipe, 216.
Clinton, De Witt, locomotive, 288.
Coal, 64.
anthracite, 66.
anthracite, composition of different kinds of, 66.
anthracite, evaporative efficiency of, 68.
anthracite, quantity of air required for combustion of, 67.
bituminous, 68.
bituminous, composition of, 68.
Cohesion, 261.
Coke, 69.

Combustion, 63.
available heat of, 65.
of fuel in locomotive furnaces, 210.
spontaneous, 73.
Compound motion, 264.
Construction of locomotives, 118.
Crank-pin, rule to find diameter of, 117.
Crown-bars, 203.
Crushing strength, 26.
Cugnot's locomotive, 158.
Cylinder, mensuration of, 242.

Dampers, 217.
Danforth passenger locomotive, 48
Decimal equivalents, table of, 245.
Detrusive strength, 261.
Diameter of circles, table of, 247, 267.
Distance by railroad between important places in U. S., 292.
Distances from Philadelphia to cities and towns in U. S. by shortest routes, 295.
Driving-axles, brasses for, 159.
Dynamic equivalent of heat, 58.

Ebullition or boiling of water, 27.
Eccentric-rods, 136.
length of, 137.
positions of, on shaft, formula to find, 137.
Eccentrics, 134.
Elastic fluids and vapors, 49.
Elasticity, 186.
Elasticity of steam, 82.
Engine, power of the, 96.
tank, 128.
Engines, stationary, 99.
Engineers, locomotive, 21.
hints to, 234.

Equivalent, dynamic, of heat, 58.
mechanical, of heat, 56.
Equivalents, decimal, table of, 245.
Evans', Oliver, locomotive, 254.
Evaporation of water, 27.
why produces cold, 52.
Exhaust-nozzle, 216.
Exhaust-ports, rule to find area of, 117.
Expansion, power of, by heat, 58.
Experiments on iron boiler-plates (tables), 255, 256.
Explosions, boiler, 278.

Fairlie narrow-gauge locomotive, 136.
Feed-pump ram, rule to find diameter of, 117.
Fire, 74.
Fire-boxes, materials for, 198.
proportions of, 198.
Firemen on locomotives, 224.
on locomotives, natural qualifications of, 227.
Firing, 228.
Fixed temperatures, 47.
Flues, boiler, rule to find safe external pressure on, 185.
Fluids, conditions of equilibrium of, 50.
elastic, 49.
Force, 261.
central or centrifugal, 261.
centripetal, 261.
of heat, molecular or atomic, 59.
Forces, central and mechanical, 260.
Forney's improved tank locomotive, 125.
Friction, 261.
angle of, 260.
Fuel and air, mixture of, 65.

Fuel, combustion of, in locomotive furnaces, 210.
ingredients of, 65.
unburnt waste of, 73.
Furnaces in locomotive boilers, 192.
stayed surfaces in; strength of 199.

Gas, olefiant, 78.
Gases, 76.
compression and dilatation of, 79.
gravity acts on, 49.
liquefaction of, 79.
specific gravity of, 80.
Giffard's injector, 232.
Gradients, table of, 105.
Grate-bars, 216.
Gravity, 262.
centre of, 262.
specific, 265.
specific, of different seas, 26.
specific, of ice, 30.
specific, of water, 26, 31.
Gyration, 262.

Heat, 52, 81.
communication of, 59.
dynamic equivalent of, 58.
effects of, in circulation of water in boilers, 60.
effects of, upon different bodies, 61.
latent, 55.
latent, of various substances, 61.
mechanical equivalent of, 56.
mechanical theory of, 57.
medium, 61.
molecular or atomic force of, 59.
power of expansion by, 58.
sensible, 56.

Heat, specific, 53.
total or actual, 59
transmission of, 61.
unit of, 54.
Horse-power, actual or net, 98.
indicated, 98.
nominal, 98.
of stationary engines, 99.
of steam-engines, 99.
Hydrocarbons, 65.
Hydrodynamics, 262.
Hydrogen, 77.
carburetted, 77.
Hyperbolic logarithms, 263.

Ice, latent heat of, 27.
specific gravity of, 30.
Impetus, 263.
Inclined plane, 263.
Incrustation of steam-boilers, 272.
Indicator, the, 263.
Indicators, speed, 161.
Inertia, 262.
Injector, action of the, 231.
accumulation of power, 232.
Rue's "Little Giant," 230.
how to put on, 233.
method of working, 234.
table of capacities, 237.
Injectors, table of capacities of, 235
Instructions for care and management of locomotive boilers, 222.
"***Ironsides,***" locomotive, 291.

Lap of valve, 144.
and lead, table showing amount of, 146.
Latent caloric, 52.
heat, 55.
heat of water or ice, 27.
Lateral motion, 160.
Lateral pressure of water, 251.
Lead of valve, 145.
Link, the, 147.
adjustment of the, 152.
Liquefaction of gases, 78.
Load, safe, 186.
Locomotive, the, 17.
adhesive power of the, 101.
age of, 130.
average proportion of different parts of, 117.
Baldwin anthracite coal-burning, 100.
building, 117.
"Charles Millard" exploded, 279
construction of, 118.
Cugnot's, 158.
cut of, 16.
Danforth passenger, 48.
dead weight in, 126.
"De Witt Clinton," the, 288.
eight-wheel passenger, 62.
Evans', Oliver, 254.
freight anthracite coal-burning, 93.
heavy, 131.
"Ironsides," 291.
Murdock's, 212.
narrow-gauge, Fairlie, 136.
number of, in the United States, 130.
number of miles run by, 130.
power of, 101.
proportions of, 107–115.
rule for calculating tractive power of, 102.
rule for finding area of exhaust-ports of, 117.
rule for finding diameter of crank-pin of, 117.
rule for finding diameter of feed-pump ram of, 117.

Locomotive, rule for finding diameter of piston-rod of, 117.
rule for finding diameter of steam-pipe of, 117.
rule for finding horse-power of, 102.
rule for finding power of, 106.
rule for finding size of steam-ports for, 117.
setting the valves of, 121.
Stephenson's, George, 277.
theory of the, 24.
tractive force of, 101.
tractive power of, rules for calculating, 102.
Logarithms, 263.
hyperbolic, 263.

Mechanical equivalent of heat, 52.
power, 263.
properties of vapor, 80.
theory of heat, 57.
Mensuration of the circle, cylinder, sphere, etc., 242.
Mercury, expansion of, 46.
properties of, 43.
Molecular or atomic force of heat, 59.
Momentum, 264.
Motion, 264.
absolute, 264.
accelerated, 264.
angular, 264.
compound, 264.
lateral, 160.
natural, 264.
perpetual, 265.
relative, 264.
retarded, 264.
uniform, 264.
Movers, prime, 265.
Murdock's locomotive, 212.
Narrow-gauge locomotive, Fairlie, 136.
Natural motion, 264.
Nitrogen, 78.
Nozzle, exhaust, 216.
Number of miles of railroad in the world in 1873, 298.

Olefiant gas, 78.

Packing for pistons and valve-rods, 156.
metallic, 157.
piston-rod, rule to find size of, 158.
spring cylinder, setting out, 155.
steam and spring cylinder, 154.
valve-rod, rule to find size of, 158.
Pendulum, 265.
Percussion, 265.
Perpetual motion, 265.
Petticoat-pipe, 216.
Piston-rod, rule to find diameter of, 117.
Plane, inclined, 263.
Pneumatics, 265.
Power, 263.
mechanical, 263.
of expansion by heat, 58.
of locomotive, rule for finding, 106.
Pressure of air, 34, 35.
safe working, 186.
Prime movers, 265.

Radiation of caloric, 51.
Railroad, number of miles of, in the world in 1873, 298.
trains, resistance of air against, 38.

Railroad trains, resistance of air against, table showing, 40.
Railroads, speed on, 131.
Reflection of caloric, 51.
Relative motion, 264.
Resistance to motion caused by the air, 38.
Retarded motion, 264.
" **Rocket,**" the locomotive, 277.
Rods, eccentric, 136; length of, 137.
Rue's "Little Giant" injector, 230–3.
Rule to find area of exhaust-ports, 117.
to find diameter of crank-pin, 117.
to find diameter of feed-pump ram, 117.
to find diameter of piston-rod, 117.
to find diameter of steam-pipe, 117.
to find elasticity of steel springs, 252.
to find heating surface in locomotive boilers, 174.
to find heating surface in stationary boilers, 175.
to find heating surface in tubes of locomotive boilers, 175.
to find horse-power of locomotives, 102.
to find power of locomotives, 106.
to find quantity, height, etc., of water in steam-boilers, 250.
to find safe external pressure on boiler flues, 185.
to find safe working pressure of steel boilers, 184.
to find size of piston-rod packing, 158.
Rule to find size of steam-ports, 117.
to find size of valve-rod packing, 158.
to find tractive power of locomotives, 102.
Rules to be followed in case of accidents, 285.

Safety-valves, 217.
table showing rise of, under different pressures, 220.
Scalds, 287.
Seams, boiler, punched and drilled holes for, 176.
single and double riveted, 176.
single and double riveted, comparative strength of, 180.
Sensible caloric, 52.
heat, 56.
Signals, 238.
Slide-valve, 139.
balanced, 145.
friction on, 143.
Smoke-box, 213.
Smoke-stacks, 214.
Specific gravity, 265.
gravity of ice, 30.
gravity of gases, 80.
gravity of water, 26, 31.
heat, 53.
Speed indicators, 161.
Sphere, mensuration of, 242.
Spontaneous combustion, 73.
Springs, steel, rules for finding elasticity of, 252.
Stay-bolts, 201.
Stationary engines, 99.
Steam, 80.
elasticity of, 82.
mechanical properties of, 80.
pressure of, 86.

Steam superheated, 88.
temperature of, 86.
Steam-engines, horse power of, 94.
power of, 96.
Steam-gauges, 221.
Steam-pipe, rule to find diameter of, 117.
Steam-ports, 132.
rule to find size of, 117.
Steel, 195.
plates, table showing tensile strength of, 259.
Stephenson's, Geo., locomotive, 277.
Strength, 266.
animal, 260.
crushing, 261.
detrusive, 261.
tensile, 186.
torsional, 266.
transverse, 266.
working, 186.

Table containing diameters, circumferences, and areas of circles, 267, 271.
deducted from experiments on boiler plates, 255, 256.
of areas of external surfaces and diameters of tubes, 207–209.
of boiler pressures, 188, 191.
of capacities of injectors, 235.
of decimal equivalents, 245.
of diameters, circumferences, and areas of circles, 247, 248.
of gradients, 105.
of temperatures required for the ignition of different combustible substances, 75.
showing actual extension of wrought-iron at various temperatures, 256.
Table showing amount of lap and lead on valves, 146.
showing effects of heat upon different bodies, 61.
showing expansion of air by heat, 37.
showing number of revolutions per minute by drivers, 129
showing resistance of air against railroad trains, 40, 41.
showing rise of safety-valves under different pressures, 220.
showing specific gravity of different seas, 26.
showing temperature of steam, etc., 91, 92.
showing tensile strength of cast-iron, 257.
showing tensile strength of steel plates, 259.
showing time at 80 different places when it is 12 M. at N. Y. city, 289.
showing tensile strength of wrought-iron, 258.
showing total heat of combustion of various fuels, 74.
showing velocity of escape and pressure of steam, 89.
showing weight of water, 31, 249.
Tank engine, 128.
Temperatures, fixed, 47.
Tensile strength, 186.
Theory, mechanical, of heat, 57
Thermometer, the, 43.
absolute zero, 46.
centigrade scale, 45.
change of zero, 46.
comparative scale of English, French, and German, 42.
Fahrenheit's, 44.

Thermometer, mercurial, 44.
Reaumer's, 45.
solid, 47.
spirit, 47.
standard points of, how ascertained, 44.
Tools, wrecking, 239.
Torsion, 266.
Torsional strength, 266.
Tractive power of locomotives, 102.
Trammel-gauge, 122.
Transverse strength, 266.
Tubes, 203.
breaking of, 205.
burning of, 204.
corrosion of, 205.
leakage of, 205.
length and diameter of, 205.
resistance of, 204.
sagging of, 205.
steel, 203, 205.
table of areas of external surfaces and diameters of, 207-209
wearing of, 204.

Uniform motion, 264.
Unit of heat, 54.

Valve, lap and lead of, 144.
position of, at full stroke, 139.
position of, at half stroke, 140.
position of, when link is in mid-gear, 141.
travel of, 145.
rods, length of, 144.
rods, packing for, 156.
slide, 139.
slide, balanced, 145.
slide, friction on, 143.
Valves of locomotives, setting the, 121.
safety, 217.
safety, table showing rise of, under different pressures, 220.
Vapors, elastic, 49.
Velocity, 266.
Vocabulary, 299.

Water, 25.
boiling point of, 29.
composition of, 26.
discharge of, 251.
ebullition or boiling of, 27.
evaporation of, 27.
for the production of steam, 26
latent heat of, 27.
lateral pressure of, 251.
passing into steam, 86.
pressure of, 251.
rules to find quantity, height, etc., in steam boilers, 250.
specific gravity of, 26, 31.
weight of (tables), 31, 32, 249.
Weights and measures, 266.
measures, etc., useful numbers in calculating, 240, 241.
Work, 266.
Working-pressure, safe, 186.
strength, definition of, 186.
Wrecking-tools, 239.
Wrought-iron, table showing actual extension of, 256.
table showing tensile strength of, 258.

Zero, absolute, 46.
change of, 46.

THE END

ROPER'S
Hand-Book of Land and Marine Engines. PRICE. $3.50

ROPER'S
Hand-Book of the Locomotive. 2.50

ROPER'S
Hand-Book of Modern Steam Fire-Engines. 3.50

ROPER'S
Catechism of High-Pressure or Non-Condensing Steam-Engines. 2.00

ROPER'S
Engineer's Handy-Book. 3.50

ROPER'S
Instructions and Suggestions for Engineers and Firemen. 2.00

ROPER'S
Care and Management of the Steam-Boiler. 2.00

ROPER'S
Simple Process for Estimating the Horse-Power of Steam-Engines. .50

ROPER'S
Questions and Answers for Engineers. 3.00

ROPER'S
Use and Abuse of the Steam-Boiler. 2.00

ROPER'S
Young Engineer's Own Book. 3.00

INTRODUCTION.

THE object of the writer in preparing these works has been to present to the practical engineer a set of books to which he can refer with confidence for information regarding every branch of his profession. Up to the date of the publication of these books, it was impossible to find a plain and practical treatise on the steam-engine. This arose, perhaps, from the fact that men who had attained proficiency in steam-engineering had no taste for devoting their limited leisure time to writing, and that those whose circumstances enabled them to do so, were precluded from a want of that practical knowledge which is only obtained by years of hard work and close observation. Many of the books heretofore written on the steam-engine are full of formulæ for calculating questions that may arise in the engine-room; but, as they are generally expressed in algebraical form, they are of little service to the majority of engineers; for, however useful such formulæ may be to the scientific, they can be of no practical value to men who do not fully understand them. It is also no less a fact, that nearly all writers on the steam-engine deal more with the past than the present. This is to be regretted, for, however interesting the by-gone records of steam-engineering may be as a history, they cannot instruct the engineer of the present day in the principles and practice of his profession.

An experience of over thirty years, with all kinds of engines and boilers, enables the writer to fully understand the kind of information most needed by men having charge of steam-engines of every description, and what they could comprehend and employ. With this object in view, he has carefully investigated all the details of stationary, locomotive, fire, and marine engines, taking up each subject singly, and excluding therefrom everything not directly connected with steam-engineering. Particular attention has been given to the latest improvements in all these classes of engines, and their proportioning according to the best modern practice, which will be of immense value to engineers, as nothing of the kind has heretofore been published. They also contain ample instructions for setting up, lining, reversing, and setting the valves of all classes of engines — subjects that have not received that attention from other writers on the steam-engine which their importance so justly merits. A certain portion of each book is devoted to an examination and discussion of the principles of Hydro- and Thermo-Dynamics, which include Air, Water, Heat, Combustion, Steam, Liquefaction, Dilatation of Gases, Molecular and Atomic Forces, Dynamic Equivalents, subjects with which the practical engineer should be fully conversant; as to ignore the principles of any subject is similar to building a structure without knowing the strength of the foundation; for it is only by a minute and careful analysis of the physical phenomena which convert heat into a motor force that the steam-engine has been brought to its present perfection.

S. R.

HAND-BOOK

OF

LAND AND MARINE ENGINES;

INCLUDING

THE MODELLING, CONSTRUCTION, RUNNING, AND MANAGEMENT OF LAND AND MARINE ENGINES AND BOILERS.

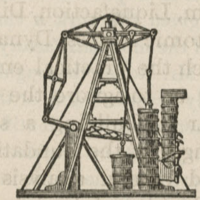
Fully Illustrated.

BY

STEPHEN ROPER, ENGINEER,

Author of

Roper's Catechism of High-Pressure or Non-Condensing Steam Engines," "Roper's Hand-Book of the Locomotive," "Roper's Hand-Book of Modern Steam Fire-Engines," "Roper's Handy-Book for Engineers," "Roper's Improvements in Steam-Engines," "Roper's Use and Abuse of the Steam-Boiler," "Questions for Engineers," etc.



MARINE BEAM-ENGINE.

PHILADELPHIA:
EDWARD MEEKS.

Roper's Hand-book of Land and Marine Engines.

Opinions of the Press.

Iron Age, New York.

THE author of this hand-book says, in his preface, that his object in preparing it, "has been to present to the practical inquirer a book to which he can refer with confidence for information in regard to every branch of his profession."

Rules and directions expressed in algebraic formulæ are of little service to the majority of engineers, because they are not fully understood. The author, keeping this in mind, has avoided most of the points which render many of our hand-books of limited value to the practical man. He has had a long and extensive practical experience among the men for whom he writes, and understanding their wants, has produced a book which seems admirably adapted to those who have anything to do, in a practical way, with steam machinery. We have given the work a careful examination, and consider it one of the most satisfactory works of the kind we have ever seen. Mr. Roper thoroughly understands his subject, being entirely practical, and, at the same time, having a correct understanding of scientific principles. His chapters on the theory of steam engineering are so simple and practical that there is no mechanic in the country, however ignorant he may be of higher mathematics, who cannot learn all they are intended to teach. His practical directions for the management of engines are just such as we should expect from an experienced engineer who had spent all his

life in an engine-room, but who had learned the theory as well as the practice of his trade. They are plain and to the point, and the reader may accept them with an entire confidence. His descriptions of engines, pumps, and the appliances connected with engines, are exceedingly satisfactory, as are also his rules, which seem to be the best and simplest which could be formulated. The book has an abundance of tabular information, which seems to include all the tables that could be of any use. The engravings are good, and are just what is wanted to explain the text. In a word, the amount and kind of information contained in this work seems to be all that could be desired. The owner of a steam-engine cannot well do without it, and no one who runs an engine should be ignorant of any part of its contents.

CONTENTS.

INTRODUCTION.
THE STEAM-ENGINE.
STEAM.
Table showing the Temperature and Weight of Steam at different Pressures from one Pound per Square Inch to 300 Pounds, and the Quantity of Steam produced from 1 Cubic Inch of Water, according to Pressure.
ECONOMY OF WORKING STEAM EXPANSIVELY.
Table of Hyperbolic Logarithms to be used in Connection with the above Rule.
Table showing the average Pressure of Steam upon the Piston throughout the Stroke, when Cut-off in the Cylinder from $\frac{1}{8}$ to $\frac{7}{11}$, commencing with 25 Pounds and advancing in 5 Pounds up to 130 Pounds Pressure.
Table of Multipliers by which to find the mean Pressure of Steam at various points of Cut-off.
HIGH-PRESSURE OR NON-CONDENSING STEAM-ENGINES.
POWER OF THE STEAM-ENGINE.
Foreign Terms and Units for Horse-power.
Table of Factors.
WASTE IN THE STEAM-ENGINE.
DESIGN OF STEAM-ENGINES.
THE BED-PLATE.
CYLINDERS.
Table showing the proper Thickness for Steam-cylinders of different Diameters.

PISTONS.
PISTON-RINGS.
PISTON-SPRINGS.
STEAM-PISTONS.
SOLID PISTONS.
Table of Piston Speeds for all Classes of Engines — Stationary, Locomotive, and Marine.
PISTON, CONNECTING-ROD, AND CRANK CONNECTION.
Table showing the Position of the Piston in the Cylinder at different Crank-angles, according to the length of Connecting-rod.
Table showing length of Stroke and Number of Revolutions for different Piston Speeds in Feet per Minute.
PISTON-RODS.
CRANK-PINS.
Table showing the Angular Position of the Crank-pin corresponding with the various Points in the Stroke which the Piston may occupy in the Cylinder.
STEAM-CHESTS.
VALVE-RODS.
GUIDES.
ROCK-SHAFTS.
CROSS-HEADS.
STEAM-PORTS.
Table showing the Proper Area of Steam-ports for different Piston Speeds.
SLIDE-VALVES.
PROPORTIONS OF SLIDE-VALVES.
LAP ON THE SLIDE-VALVE.
POPPET OR CONICAL VALVES.
Table showing the Amount of "Lap" required for Slide-valves of Stationary Engines when the Steam is to be Worked expansively.

Lead of the Slide-valve.
Clearance.
Compression.
Friction of Slide-valves.
Balanced Slide-valves.
Fitting Slide-valves.
Slide-valve Connections.
Eccentrics.
Eccentric-rods.
Cranks.
Crank-shafts.
Pillow-blocks, or Main Bearings.
Fly-wheels.
Link-motion.
Proportions of Steam-engines according to the best Modern Practice.
Setting up Engines.
Dead-centre.
How to put an Engine in Line.
How to Reverse an Engine.
Setting Valves.
How to set a Slide-valve.
Setting out Piston Packing.
Piston- and Valve-rod Packing.
Automatic Cut-offs.
Governors.
The Huntoon Governor.
The Allen Governor.
The Cataract.
Wright's High-pressure Engine.
Hawkins and Dodge's High-pressure Engine.
Watts and Campbell's High-pressure Engine.
The Buckeye High-pressure Engine.

Wheelock's High-pressure Engine.
The Corliss High-pressure Engine.
Hampson and Whitehill's High-pressure Engine.
The Allen High-pressure Engine.
Woodruff and Beach's High-pressure Engine.
Naylor's Vertical High-pressure Engine.
Williams' Vertical Three-cylinder High-pressure Engine.
Roper's Caloric Engine.
Haskins' Vertical High-pressure Engine.
Massey's Rotary Engine.
Portable Engines.
How to Balance Vertical Engines.
Knocking in Engines.
The Injector.
Pumps.
Force-pumps.
Piston-pumps.
Boiler Feed-pumps.
Steam-pumps
The Atlas Steam-pump.
The Dayton Cam-pump.
Directions for setting up Steam-pumps.
The Pulsometer.
James Watt.
Condensing or Low-pressure Steam-engines.
Explanation of the working Principles of the Condensing Engine.
Horse-power of Condensing Engines.
The Vacuum.
Marine Steam engines.
Compound Engines.

DIRECT-ACTING ENGINES.
BALANCING THE MOMENTUM OF DIRECT-ACTING ENGINES.
OSCILLATING ENGINES.
TRUNK ENGINES.
GEARED ENGINES.
BACK-ACTION ENGINES.
SIDE-LEVER ENGINES.
BEAM ENGINES.
MARINE BEAM ENGINE.
STARTING-GEAR FOR MARINE ENGINES.
CONDENSERS.
AIR-PUMPS.
THE HYDROMETER, SALINOMETER, OR SALT-GAUGE.
THE MANOMETER.
THE BAROMETER.
MARINE ENGINE REGISTER, CLOCK, AND VACUUM GAUGE.
STEAM-GAUGES.
GLASS WATER-GAUGES.
THE STEAM-ENGINE INDICATOR.
METHOD OF APPLYING THE INDICATOR.
FORM OF DIAGRAMS.
HOW TO KEEP THE INDICATOR IN ORDER.
THE DYNAMOMETER.
THE ENGINEER.
MANAGEMENT OF LAND AND MARINE ENGINES.
HOW TO PUT THE ENGINES IN A STEAMBOAT OR SHIP.
SCREW-PROPELLERS.
PADDLE-WHEELS.
FLUID RESISTANCE.
Signification of Signs used in Calculations.

DECIMAL.
Decimal Equivalents of Inches, Feet, and Yards.
Decimal Equivalents of Pounds and Ounces.
Useful Numbers in calculating Weights and Measures, etc.
Decimal Equivalents to the Fractional Parts of a Gallon or an Inch.
UNITS.
THEORY OF THE STEAM-ENGINE.
WATER.
AIR.
THE THERMOMETER.
Comparative Scale of Centigrade, Fahrenheit, and Reaumer Thermometers.
ELASTIC FLUIDS.
CALORIC.
HEAT.
COMBUSTION.
GASES.
STEAM-BOILERS.
STEAM-DOMES.
MUD-DRUMS.
SETTING BOILERS.
EXPANSION AND CONTRACTION OF BOILERS.
TESTING BOILERS.
NEGLECT OF STEAM-BOILERS.
CARE AND MANAGEMENT OF STEAM-BOILERS.
HEATING SURFACE.
RULES FOR FINDING THE HEATING SURFACE OF STEAM-BOILERS.
EVAPORATIVE EFFICIENCY OF BOILERS.
HORSE-POWER OF BOILERS.

FIRING.
INSTRUCTIONS FOR FIRING.
RULES FOR FINDING THE QUANTITY OF WATER BOILERS AND OTHER CYLINDRICAL VESSELS ARE CAPABLE OF CONTAINING.
LONGITUDINAL AND CURVILINEAR STRAINS.
RULES.
EXPLANATION OF TABLES OF BOILER PRESSURES ON FOLLOWING PAGES.
Table of safe Internal Pressures for Iron Boilers.
Table of safe Internal Pressures for Steel Boilers.
MARINE BOILERS.
Proportions of Heating Surface to Cylinder and Grate Surface of noted Ocean, River, and Ferry-boat Steamers.
SETTING MARINE BOILERS.
BEDDING MARINE BOILERS.
CLOTHING MARINE BOILERS.
CARE OF MARINE BOILERS.
REPAIRING STEAM-BOILERS.
TUBES.
Table of Superficial Areas of External Surfaces of Tubes of Various Lengths and Diameters in Square Feet.
BOILER FLUES.
BOILER-HEADS.
SAFETY-VALVES.
Table showing the Rise of Safety-valves, in Parts of an Inch, at different Pressures.
RULES.
FOAMING.
INCRUSTATION IN STEAM-BOILERS.

INTERNAL AND EXTERNAL CORROSION OF STEAM-BOILERS.
BOILER EXPLOSIONS.
COMPARATIVE STRENGTH OF SINGLE AND DOUBLE-RIVETED SEAMS.
CALKING.
STRENGTH OF THE STAYED AND FLAT SURFACES.
DEFINITIONS AS APPLIED TO BOILERS AND BOILER MATERIALS.
FEED-WATER HEATERS.
Table showing the Units of Heat required to Convert One Pound of Water, at the Temperature of 32° Fah., into Steam at different Pressures.
STEAM-JACKETS.
LOSS OF PRESSURE IN CYLINDERS INDUCED BY LONG STEAM-PIPES.
PRIMING IN STEAM-CYLINDERS.
OILS AND OILING.
Table of Coefficients of Frictions between Plane Surfaces.
GRATE-BARS.
CHIMNEYS.
Table showing the proper Diameter and Height of Chimney for any kind of Fuel.
SMOKE.
MENSURATION OF THE CIRCLE, CYLINDER, SPHERE, ETC.
CENTRAL AND MECHANICAL FORCES AND DEFINITIONS.
THE CIRCLE.
Table containing the Diameters, Circumferences, and Areas of Circles, and the Contents of each in Gallons, at 1 Foot in Depth.

CONTENTS.

LOGARITHMS.
Table of Logarithms of Numbers from 0 to 1000.
HYPERBOLIC LOGARITHMS.
Table of Hyperbolic Logarithms.
Table containing the Diameters, Circumferences, and Areas of Circles from $\frac{1}{16}$ of an Inch to 100 Inches.
RULES FOR FINDING THE DIAMETER AND SPEED OF PULLEYS.
GEARING.
BELTING.
CEMENT FOR MAKING STEAM-JOINTS AND PATCHING STEAM-BOILERS.
NON-CONDUCTORS FOR STEAM-PIPES AND STEAM-CYLINDERS.
HOW TO MARK ENGINEERS' OR MACHINISTS' TOOLS.
TO POLISH BRASS.
SOLDER.
Table showing Weight of different Materials.
JOINTS.
THE INVENTION AND IMPROVEMENT OF THE STEAM-ENGINE.

HAND-BOOK

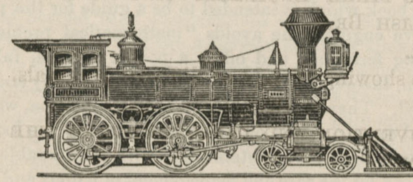
OF THE

LOCOMOTIVE;

INCLUDING THE

CONSTRUCTION, RUNNING, AND MANAGEMENT OF LOCOMOTIVE ENGINES AND BOILERS.

Fully Illustrated.



BY

STEPHEN ROPER, ENGINEER,

Author of
"Roper's Catechism of High-Pressure or Non-Condensing Steam-Engines," "Roper's Hand-Book of Land and Marine Engines," "Roper's Hand-Book of Modern Steam Fire-Engines," "Roper's Handy-Book for Engineers," "Roper's Improvements in Steam-Engines," "Roper's Use and Abuse of the Steam-Boiler," "Questions for Engineers," etc.

PHILADELPHIA:
EDWARD MEEKS.

ROPER'S HAND-BOOK
OF
THE LOCOMOTIVE.

OPINIONS OF THE PRESS.

Scientific American, New York.

The author of this work very truly believes that in a book, as in a clock, any complication of its machinery has a tendency to impair its usefulness and affect its reliability. Hence, in preparing a book which is intended to be a guide for the practical locomotive engineer, he avoids "mathematical problems and entangling formulæ," and offers a pocket volume, full of information, theoretical as well as practical, succinctly and clearly condensed. There are chapters on heat, combustion, water, air, gases and steam; others on the construction of the locomotive and of its various parts, entered into with considerable details; instructions for the care and management of boilers and engines, tables of strength of materials, and useful practical hints for the guidance of the engineer. In brief, the volume is, as its name indicates, a hand-book to which the locomotive mechanic can turn for information regarding almost every branch of his trade. It is neatly illustrated and bound in morocco, in convenient pocket-book form.

North American and United States Gazette, Phila.

Mr. Roper asserts as a preliminary qualification for his task, that he has had more than thirty years' experience with all

classes of steam-engines and boilers. The object of the work is to convey practical knowledge of all that appertains to the locomotive engine and boiler, in a practical manner. Stationary and marine engines are omitted, because other treatises furnish all that need be known of them. Mr. Roper seems to know *exactly* what the class for whom he writes require, and what they can comprehend and employ. His opinion, as expressed in his work, is the highest compliment ever paid to those in question, and to the railways of this country, by which this skill has been created and is sustained and promoted. The mechanical and dynamical equivalents of heat and its molecular force are treated in a clear and lucid manner. Chemical equivalents, the liquefaction and dilatation of gases, superheated steam, tractive and evaporative power, combustion, mensuration, incrustation, and similar subjects are discussed. The strictly mechanical information is fully and lucidly set forth, to an extent that would gain a degree in any of our schools. But beyond the rudiments, and beyond their combinations and applications, there is the pervading idea that the American engineer aims to know the effect by its cause—seeks philosophical knowledge as a part of his employment, and not only seeks, but, as a whole, has mastered so much that he deserves a standard in pure science very few have supposed. No higher compliment could be paid, and it could be paid nowhere else. The treatise apparently omits nothing, expresses clearly though compactly, furnishes tables, and is a fine tribute to the practical ability of the country. It contains suitable illustrations, and is appropriately prefaced with a portrait of M. W. Baldwin.

CONTENTS.

INTRODUCTION.
THE LOCOMOTIVE.
LOCOMOTIVE ENGINEERS.
THEORY OF THE LOCOMOTIVE.
WATER.
AIR.
COMPARATIVE SCALE OF ENGLISH, FRENCH, AND GERMAN THERMOMETERS.
THE THERMOMETER.
ELASTIC FLUIDS AND VAPORS.
CALORIC.
HEAT.
COMBUSTION.
GASES.
STEAM.
Table showing the Velocity with which Steam of Different Pressures will flow into the Atmosphere or into Steam of lower Pressure.
Rule for finding the Superficial Feet of Steam-pipe required to Heat any Building with Steam.
Table showing the Temperature of Steam at Different Pressures from 1 pound per Square Inch to 240 pounds, and the Quantity of Steam produced from a Cubic Inch of Water, according to Pressure.
HORSE-POWER OF STEAM-ENGINES.
Rule for finding the Horse-power of Stationary Engines.
THE POWER OF THE LOCOMOTIVE.

Rule for finding the Horse-power of a Locomotive.
Rules for calculating the Tractive Power of Locomotives.
Table of Gradients.
Adhesive Power of Locomotives.
Proportions of Locomotives, according to best Modern Practice.
Proportions of Different Parts of Locomotives, according to best Modern Practice.
Table showing the Travel of Valve and the Amount of Lap and Lead for Different Points of Cut-off, and the Distance the Steam follows the Piston on the Forward Motion.
RULES.
LOCOMOTIVE BUILDING.
CONSTRUCTION OF LOCOMOTIVES.
SETTING THE VALVES OF LOCOMOTIVES.
DEAD WEIGHT IN LOCOMOTIVES.
Table showing the number of Revolutions per minute made by Drivers of Locomotives of different Diameters and at different Speeds.
STEAM-PORTS.
BRIDGES.
ECCENTRICS.
ECCENTRIC RODS.
Formula by which to find the Positions of the Eccentric on the Shaft.
THE SLIDE-VALVE.
FRICTION ON THE SLIDE-VALVE.
LAP AND LEAD OF VALVE.
BALANCED SLIDE-VALVE.
Table showing the Amount of Lap and Lead on the

Valves of Locomotives in Practice, on thirty-five of the principal Railroads in this Country.
THE LINK.
ADJUSTMENT OF THE LINK.
STEAM AND SPRING CYLINDER PACKING FOR LOCOMOTIVES.
Rule for finding the size of Piston- and Valve-rod Packing.
BRASSES FOR DRIVING-AXLES OF LOCOMOTIVES.
LATERAL MOTION.
SPEED INDICATORS.
LOCOMOTIVE BOILERS.
PROPORTIONS OF THE LOCOMOTIVE BOILER, FROM THE BEST MODERN PRACTICE.
WAGON-TOP AND STRAIGHT BOILERS.
THE EVAPORATIVE POWER OF LOCOMOTIVE BOILERS.
HEATING SURFACE, STEAM ROOM, AND WATER SPACE IN LOCOMOTIVE BOILERS.
HEATING SURFACE TO GRATE SURFACE IN STEAM BOILERS.
Rule for finding the Heating Surface in Locomotive Boilers.
Rule for finding the Heating Surface in the Tubes of Locomotive Boilers.
Rule for finding the Heating Surface in Stationary Boilers.
PUNCHED AND DRILLED HOLES FOR THE SEAMS OF LOCOMOTIVE BOILERS.
MACHINE AND HAND RIVETING FOR LOCOMOTIVE BOILERS.
COMPARATIVE STRENGTH OF SINGLE AND DOUBLE RIVETED BOILER SEAMS.

FURNACES OF LOCOMOTIVE BOILERS.
PROPORTIONS OF FIRE-BOXES, FROM THE BEST MODERN PRACTICE.
STRENGTH OF STAYED SURFACES IN THE FURNACES OF LOCOMOTIVE BOILERS.
STAY-BOLTS.
CROWN-BARS.
TUBES.
COMBUSTION OF FUEL IN LOCOMOTIVE FURNACES.
SMOKE-BOX.
SMOKE-STACKS.
EXHAUST-NOZZLE.
SAFETY-VALVES.
Table showing the Rise of the Safety-valves.
STEAM-GAUGES.
INSTRUCTIONS FOR THE CARE AND MANAGEMENT OF LOCOMOTIVE BOILERS.
FIREMEN ON LOCOMOTIVES.
FIRING.
THE INJECTOR.
SIGNALS.
WRECKING TOOLS.
RULES FOR FINDING THE ELASTICITY OF STEEL SPRINGS.
CENTRAL AND MECHANICAL FORCES AND DEFINITIONS.
Table containing Diameters, Circumferences, and Areas of Circles, etc.
INCRUSTATION IN STEAM-BOILERS.
BOILER EXPLOSIONS.
VOCABULARY OF TECHNICAL TERMS AS APPLIED TO THE DIFFERENT PARTS OF LOCOMOTIVES.

HAND-BOOK

OF MODERN

STEAM FIRE-ENGINES;

INCLUDING

THE RUNNING, CARE, AND MANAGEMENT OF STEAM FIRE-ENGINES AND FIRE-PUMPS.

With Illustrations.

BY

STEPHEN ROPER, ENGINEER,

Author of

"Roper's Catechism of High-Pressure or Non-Condensing Steam-Engines," "Roper's Hand-Book of the Locomotive," "Roper's Hand-Book of Land and Marine Engines," "Roper's Engineer's Handy-Book," "Roper's Improvements in Steam-Engines," "Roper's Use and Abuse of the Steam-Boiler," "Questions for Engineers," etc., etc.

PHILADELPHIA:
EDWARD MEEKS.

ROPER'S HAND-BOOK

OF

MODERN STEAM FIRE-ENGINES.

OPINIONS OF THE PRESS.

The Iron Age, N. Y.

IN this work the author has done for the steam fire-engine what has been long needed, by giving us a manual which is as useful as any of those which treat of the steam-engine in other and better understood forms. This, if we are not mistaken, has never been done before, and what a fireman needed to know about his "steamer" he had to learn by experience or word of mouth, or else go in ignorance. Mr. Roper has aimed to tell just what a man needs to know about the care and management of this class of engines. The work was a difficult one, but the author has been very successful. The attempt to make literature, or begin a literature for a new department of mechanics, is a very difficult one, and this latter is the task which the author has been called upon to undertake. It is comparatively easy to compile a text-book or pocket manual when the matter is already at hand, but in this case there has been very little available matter, the greater part of the work apparently being original and gathered from a great variety of sources. The tables of performances are very interesting, and are the first which we remember to have seen. Proportions for pumps of various kinds is another valuable table. Much that pertains to the machine simply as a steam-engine is, of course, similar to what would be found in any treatise upon the steam-engine. The work is a very creditable one to the author, and is, in some respects, an improvement upon any of his earlier works.

CONTENTS.

The Steam Fire-engine.
Fire.
Precautions against Fires.
What to do in Case of Fire.
Means of Preventing Fires.
Different Methods of Extinguishing Fires.
Fire-escapes.
Fire-proof Buildings.
Losses by Fire.
Ahrens' Steam Fire-engine.
Air.
Elastic Fluids.
Air-vessels.
Clapp and Jones' Steam Fire-engine.
Water.
Silsby Rotary Steam Fire-engine.
Method of Working the Steam in the Silsby Rotary Engine.
Rules.
Steam Fire-engines.
Names of Principal Manufacturers of Steam Fire-engines in this Country.
Amoskeag Steam Fire-engine.
Early Forms of Steam Fire-engines.
Floating Steam Fire-engines.
Self-propelling Steam Fire-engines.

The Button Steam Fire-engine.
Trials of Steam Fire-engines.
Instructions for the Care and Management of Steam Fire-engines and Boilers.
Engineers.
Firemen.
Useful Information for Engineers and Firemen.
Paid and Volunteer Fire Departments.
Fire-alarms.
The Gould Steam Fire-engine.
Routine of Business in Paid Fire Departments.
The Jeffer's Steam Fire-engine.
Fire-hose.
Hose-couplings.
Dimensions of First and Second Class Steam Fire-engines.
Horizontal Distances thrown by Modern Steam Fire-engines.
Perpendicular Heights thrown by Modern Steam Fire-engines.
High-pressure or Non-condensing Steam-engines — Fire, Locomotive, and Stationary.
Power of the Steam-engine.
Foreign Terms and Units for Horse-power.
The Power or Horse-power of the Locomotive.
Rules for Calculating the Tractive Power of Locomotives.
Neafie and Levy's Steam Fire-engine.
Waste in the High-pressure or Non-condensing Steam-engines.
The Ives' Steam Fire-engine.
Different Parts of Steam-engines — The Crank.

Table showing the Angular Position of the Crank-pin Corresponding with the various Points in the Stroke which the Piston may occupy in the Cylinder.
Table of Piston Speeds for all Classes of Engines—Stationary, Locomotive, Fire, and Marine.
Table showing Position of the Piston in the Cylinder at different Crank-angles, according to the length of Connecting-rod.
Table showing Length of Stroke and Number of Revolutions for different Piston Speeds in Feet per Minute.
THE ECCENTRIC.
THE SLIDE-VALVE.
PROPORTIONS OF SLIDE-VALVES.
LAP ON THE SLIDE-VALVE.
Table showing Amount of "Lap" required for Slide-valves of Stationary Engines when the Steam is to be Worked Expansively.
LEAD OF THE SLIDE-VALVE.
FRICTION OF SLIDE-VALVES.
BALANCED SLIDE-VALVES.
COMPRESSION.
CLEARANCE.
AUTOMATIC CUT-OFFS.
SETTING VALVES.
HOW TO SET A SLIDE-VALVE.
SETTING OUT PISTON PACKING.
HOW TO REVERSE AN ENGINE.
DEAD CENTRE.
HOW TO PUT AN ENGINE IN LINE.
PROPORTIONS OF STEAM-ENGINES ACCORDING TO THE BEST MODERN PRACTICE.

Table showing Proper Thickness for Steam-cylinders of different Diameters.
THE INVENTION AND IMPROVEMENT OF THE STEAM-ENGINE.
SIGNIFICATION OF SIGNS USED IN CALCULATIONS.
DECIMALS.
Decimal Equivalents of Inches, Feet, and Yards.
Decimal Equivalents of Pounds and Ounces.
Useful Numbers in calculating Weights and Measures, etc.
Decimal Equivalents to the Fractional Parts of a Gallon or an Inch.
UNITS.
THE METRIC SYSTEM OF MEASURES AND WEIGHTS.
Metric Measures of Length.
Metric Measures of Surface.
Metric Measures of Capacity.
Metric Weights.
PUMPS.
STEAM-PUMPS.
BLAKE'S SPECIAL STEAM FIRE-PUMP.
WRIGHT'S BUCKET-PLUNGER STEAM FIRE-PUMP.
Dimensions of the Bucket-plunger Steam Fire-pumps.
PROPORTIONS OF STEAM FIRE-PUMPS.
PROPORTIONS OF BOILER FEED-PUMPS.
PROPORTIONS OF MARINE-PUMPS.
PROPORTIONS OF WRECKING-PUMPS.
PROPORTIONS OF MINING-PUMPS.
PROPORTIONS OF AIR-PUMPS.
PROPORTIONS OF TANK-PUMPS.
PROPORTIONS OF BREWERS' AND DISTILLERS' PUMPS.
THE KNOWLES' STEAM FIRE-PUMP.

EARLE'S STEAM FIRE-PUMP.
DIRECTIONS FOR SETTING UP STEAM-PUMPS.
THE ATLAS STEAM FIRE-PUMP.
CONDE'S CHALLENGE STEAM FIRE-PUMP.
HOLLY'S ROTARY STEAM FIRE-PUMP.
PROPER METHOD OF LOCATING STEAM FIRE-PUMPS.
THE INJECTOR.
THE PULSOMETER.
THE HYDRAULIC RAM.
BOILERS OF STEAM FIRE-ENGINES.
CAUSES OF FOAMING IN STEAM-BOILERS.
EVAPORATION IN STEAM-BOILERS.
INTERNAL AND EXTERNAL CORROSION OF STEAM-BOILERS.
RULES.
RULE FOR FINDING THE HEATING SURFACE OF STEAM-BOILERS.
DEFINITIONS AS APPLIED TO BOILERS AND BOILER MATERIALS.
Table of Safe Internal Pressures for Iron Boilers.
LONGITUDINAL AND CURVILINEAR STRAINS.
HEAT.
LATENT HEAT OF VARIOUS SUBSTANCES.
CALORIC.
COMBUSTION.
ENTIRE COAL PRODUCTIONS OF THE WORLD.
SPONTANEOUS COMBUSTION.
Table showing the Temperature at which different Combustible Substances will Ignite.
STEAM.
ECONOMY OF WORKING STEAM EXPANSIVELY.
CENTRAL AND MECHANICAL FORCES AND DEFINITIONS.
MENSURATION OF THE CIRCLE, CYLINDER, SPHERE, ETC.

PROPERTIES OF THE CIRCLE.
Table containing the Diameters, Circumferences, and Areas of Circles from $\frac{1}{16}$ of an Inch to 20 Inches, advancing by $\frac{1}{16}$ of an Inch up to 10 Inches, and by $\frac{1}{8}$ of an Inch from 10 Inches to 20 Inches.
LOGARITHMS.
Table of Logarithms of Numbers from 0 to 1000.
HYPERBOLIC LOGARITHMS.
Table of Hyperbolic Logarithms.
RULES FOR FINDING THE ELASTICITY OF STEEL SPRINGS.
Table showing the Actual Extension of Wrought-iron at Various Temperatures.
Table deduced from Experiments on Iron Plates for Steam-boilers, by the Franklin Institute, Phila.
Table showing the result of Experiments made on different Brands of Boiler Iron at the Stevens Institute of Technology, Hoboken, New Jersey.
HOW TO MARK ENGINEERS' OR MACHINISTS' TOOLS.
TO POLISH BRASS.
SOLDER.
CEMENT FOR MAKING STEAM-JOINTS AND PATCHING STEAM-BOILERS.
JOINTS.
RELATIVE VALUE OF FOREIGN AND UNITED STATES MONEY.
Table showing the Load that can be Carried by Man and Animals.
Man or Animal Working a Machine.
Table of Coefficients of Frictions between Plane Surfaces.
Table of Friction Coefficients for different Pressures up to the Limits of Abrasion.

A CATECHISM

OF

High-Pressure or Non-Condensing

STEAM-ENGINES;

INCLUDING

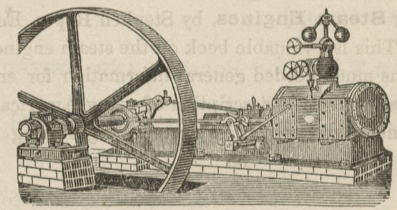
THE MODELLING, CONSTRUCTING, RUNNING, AND MANAGEMENT OF STEAM-ENGINES AND STEAM-BOILERS.

With Valuable Illustrations.

BY

STEPHEN ROPER, ENGINEER,

Author of "Roper's Hand-Book of the Locomotive," "Roper's Hand-Book of Land and Marine Engines," "Roper's Hand-Book of Modern Steam Fire-Engines," "Roper's Engineer's Handy-Book," "Roper's Improvements in Steam-Engines," "Roper's Use and Abuse of the Steam-Boiler," "Questions for Engineers," etc., etc.



PHILADELPHIA:
EDWARD MEEKS.

ROPER'S CATECHISM

OF

STEAM ENGINES.

OPINIONS OF THE PRESS.

From the North American and United States Gazette.

A Catechism of High-Pressure Steam Engines, by Stephen Roper. Mr. Roper, himself a practical engineer, has undertaken to furnish his fellow-engineers with the information experience has shown him to be most valuable. A number of tables of constant utility are furnished, and many rules and much practical advice. The work is plain rather than scientific in its language, and, claiming to be the only one expressly calculated for engineers, cannot fail to find quick demand and be of great value.

From the Scientific American.

A Catechism of High-Pressure or Non-Condensing Steam Engines, by Stephen Roper, Engineer. This is a valuable book on the steam engine. It contains much needed general information for engineers, as well as a description of many American improvements and specialties in steam engineering

CONTENTS.

Introduction.
The Steam-Engine.
Water.
Air.
Heat.
The Thermometer.
Comparative Scale of English, French, and German Thermometers.
Steam.
Table showing the Temperature of Steam at different Pressures.
The Engineer.
The Steam-Boiler.
Cylinder Boilers.
Flue Boilers.
Tubular Boilers.
Double-Deck Boilers.
Locomotive Boilers.
Mud-Drums.
Boiler-Heads.
Boiler-Shells.
Steel Boilers.
Internal and External Pressures.
Rules.
Table of Internal Pressures.
Foaming in Steam-Boilers. Rust.
Patent Steam-Boilers.
The Safety-Valve.
Feed-Water Heaters.
Fuel.
Chimneys.

Smoke.
Grate-Bars.
Duties of an Engineer in the Care and Management of the Steam-Boiler.
Steam-Engines.
Table showing the Average Pressure of the Steam upon the Piston throughout the Stroke.
Lap on the Slide-Valve.
Table showing the Amount of "Lap" required for Slide-Valves when the Steam is to be worked expansively.
Lead on the Slide-Valve.
"Cushion."
Setting Valves.
Size of Steam-Port.
Size of Steam-Pipe.
Size of Piston-Rod.
Material for Different Parts of Engines.
Proportions of Engines.
Reversing an Engine.
Putting an Engine in Line.
Setting up Engines.
Rules for the Care and Management of the Steam-Engine.
Different Kinds of Engines.
Knocking in Engines.
Vacuum.
The Indicator.
The Governor.
The Injector.
Steam-Pumps.
Centrifugal Pumps.

NOISELESS BOILER FEED-PUMP.
Directions for Setting Up Steam-Pumps.
Table containing the Diameter, Circumferences, and Areas of Circles, and the Cubical Contents of Cylinders, in Gallons.
PISTON-ROD PACKING.
INCRUSTATION.
BOILER EXPLOSIONS.
STEAM- AND FIRE-REGULATOR.
CENTRAL AND MECHANICAL FORCES.
MENSURATION.
Circle, Cylinder, Sphere, etc.
BELTING.
Leather Belts.
Lacing Belts.
Horizontal Belts.
Perpendicular Belts.
Greasing Belts.
Rules for finding the Proper Width of Belts.
RULES TO BE OBSERVED IN CASE OF ACCIDENTS.
A BRIEF HISTORY OF THE STEAM-ENGINE.
History of the Different Parts of the Steam-Engine in Detail.
VOCABULARY OF TECHNICAL TERMS as applied to Different Parts of Steam-Engines and Steam-Boilers.
PROPORTIONS of Steam-Engines according to the best modern practice.
CEMENT for making Steam-Joints and patching Steam-Boilers.
How to mark Engineers' or Machinists' Tools.
To polish Brass.
NON-CONDUCTORS for Steam-Pipes and Cylinders.

THE

ENGINEER'S HANDY-BOOK.

CONTAINING

A FULL EXPLANATION OF THE STEAM-ENGINE INDICATOR, AND ITS USE AND ADVANTAGES TO ENGINEERS AND STEAM USERS. WITH FORMULÆ FOR ESTIMATING THE POWER OF ALL CLASSES OF STEAM-ENGINES; ALSO, FACTS, FIGURES, QUESTIONS, AND TABLES FOR ENGINEERS WHO WISH TO QUALIFY THEMSELVES FOR THE UNITED STATES NAVY, THE REVENUE SERVICE, THE MERCANTILE MARINE, OR TO TAKE CHARGE OF THE BETTER CLASS OF STATIONARY STEAM-ENGINES.

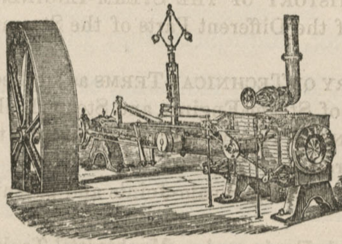
With Illustrations.

BY

STEPHEN ROPER, ENGINEER,

Author of

"Roper's Catechism of High Pressure or Non-Condensing Steam-Engines," "Roper's Hand-Book of the Locomotive," "Roper's Hand-Book of Land and Marine Engines," "Roper's Hand-Book of Modern Steam-Fire Engines," "Improvements in Steam-Engines," "Use and Abuse of the Steam-Boiler," "Questions for Engineers," etc., etc.



PHILADELPHIA:
EDWARD MEEKS.

This Book treats on every branch of

Steam Engineering

AND

Steam-Engines of Every Description

In use at the present day,—

CONDENSING, NON-CONDENSING,

SIMPLE, AND COMPOUND,

for Whatever Purpose Employed, whether for

Engineering, Manufacturing, Pumping, Locomotion, Mining, Hoisting, or Propulsion,

AND IS MORE FULLY ILLUSTRATED THAN ANY OTHER WORK EVER HERETOFORE PUBLISHED ON THE SAME SUBJECT.

OPINIONS OF THE PRESS

ON

Roper's Engineer's Handy-Book.

The Manufacturer and Builder, New York.

An Engineer's Handy-Book.—Mr. Roper, the writer of this work, is well known to many of our readers as the author of a number of useful reference books relating to steam-engineering, which have become deservedly popular by reason of their plain, intelligible style, and their freedom from unnecessary and confusing mathematical technicalities. We would be glad to see Roper's hand-books largely multiplied and distributed in every workshop, for it is only out of books of this kind that the average workman will be able to master the principles of his handiwork.

Millstone, Indianapolis, Ind.

"The Engineer's Handy-Book," by Stephen Roper, Engineer, is a practical treatise on the management of the steam-engine. The author says the book was "not written for the purpose of instructing engineers how to design or proportion steam-engines or boilers, but rather to inform them how to take care of and manage them intelligently." The declaration is carried out in the plainest and most systematic manner.

As a text-book for students in mechanical engineering, it will be found of great value. Its illustrations and tabulated matter are important features, and printed in excellent style.

National Car-Builder, New York.

Roper's Engineer's Handy-Book.—This compact and comprehensive little volume contains a vast amount of information relative to the care and management of every class of steam-engines. It is profusely illustrated, and abounds in facts, figures, rules, tables, questions and answers, formulæ, etc., that are exceedingly valuable to engineers, and of easy reference by means of a copious and well-arranged index. The various subjects are discussed with brevity and clearness, and with a freedom from technicality which enables the reader to get at the pith of the matter without fishing it out from an ocean of words. A prominent feature of the book is a full explanation of the steam-engine indicator, and its use and advantages to engineers and others.

Leffel's Illustrated News, Springfield, Ohio.

Engineer's Handy-Book: By Stephen Roper, Engineer. —The author of the valuable series of hand-books which we have before referred to, has just issued the above-named work, which must find ready way into the hands of engineers and steam-users throughout the entire land. It contains a full explanation of the steam-engine indicator, its uses and advantages, with formulæ for estimating the power of all classes of steam-engines; also facts, figures, questions, and tables for engineers who wish to qualify themselves for the United States navy, the revenue service, the merchant marine, or the better class of stationary engines.

The American Engineer, Chicago, Ill.

The Engineer's Handy-Book.—We are in receipt of the above work, which contains a description of the various forms of engines now in use, and supplies interesting and useful information as to the care, management, and remedy of defects of steam machinery and its appendages, with tables for calculating the power of engines.

American Machinist, New York.

Roper's Engineer's Handy-Book.—The subjects in this work have been treated in a brief and comprehensive way, therefore the reader is not required to read a number of chapters in order to acquire a little knowledge. The use of the indicator is treated in a plain, practical way, so that it may be readily understood. Abstruse formulas have been omitted and simple arithmetic used, thus avoiding the usual vexations among practical men who are uneducated in the higher mathematics. The author has in this book given the results of his own practical experience, which extends over a period of thirty years and upwards, and the work will doubtless be read with pleasure and profit by very many practical mechanics.

Engineering News, New York.

An "Engineer's Handy-Book."—As a writer on subjects relating to steam and steam-engineering, Mr. Roper is now too well known to need any further introduction. In this, his latest contribution to steam-engineering literature, Mr. Roper has aimed to present to his brother engineers a "handy book" that will be to them what Trautwine's "Pocket-Book" is to civil engineers, and in doing this he has spared no labor in collecting and editing his materials. Some idea of the completeness of the work may be gathered from the statement of the publishers that it contains nearly 300 main subjects, 1316 paragraphs, 876 questions and answers, 52 suggestions and instructions, 105 rules, formulæ, and examples, 149 tables, 164 illustrations, 31 indicator diagrams, and 167 technical terms; over 3000 different subjects.

Boston Journal of Commerce.

Mr. Stephen Roper is well known as the author of several other handy-books that treat on steam, steam-boilers, and engines. This new work is, in our judgment, his best.

The Scientific American, New York.

A WELL made pocket-book of practical information for mechanical engineers, particularly those of limited education, and such as may wish to qualify themselves for service in the U. S. Navy or the mercantile marine. The more important engines in use are clearly described, and formulæ are given for estimating their power. Particular attention is paid to the steam-engine indicator, its use and advantages. The author has had much experience in this class of work, and writes clearly and plainly.

The Locomotive, Hartford, Conn.

ROPER'S ENGINEER'S HANDY-BOOK.—This last work of Mr. Roper is of special value to all who have to do with steam-boilers and engines, and it will be found a valuable shop companion for the mechanic. There are a great many facts collated that are not easily reached except through expensive books and libraries. These will be found of service to all classes of men, whether in trade or manufacturing. We commend it heartily, and believe it will have a large sale.

Forest, Forge, and Farm, Ilion, N. Y.

ENGINEER'S HANDY-BOOK.—We have received a book with the above title, by the well-known author and engineer, Stephen Roper, who has written a number of works on the subject of engineering. The eminent reputation of the author is a sufficient guarantee that the book is both interesting and useful. Mr. Roper has had an experience of over thirty-five years with all kinds of engines and boilers, and thoroughly understands locomotive, fire, marine, and stationary engines.

CONTENTS.

THE ENGINEER.

FACTS THAT SHOULD BE BORNE IN MIND BY ENGINEERS.

STEAM-ENGINEERING AS A SCIENCE.

EXAMINATION OF CANDIDATES FOR CADET ENGINEERS IN THE U. S. NAVY.

INSTRUCTIONS HOW TO PREPARE FOR EXAMINATION FOR ENGINEER IN THE U. S. NAVY AND REVENUE SERVICE.

INSTRUCTIONS HOW TO OBTAIN AN ENGINEER'S LICENSE IN THE MERCANTILE MARINE SERVICE.

INSTRUCTIONS HOW TO PROCURE A LICENSE TO TAKE CHARGE OF STATIONARY ENGINES IN ANY STATE OR CITY REQUIRING IT.

THE STEAM-ENGINE INDICATOR; ITS CONSTRUCTION AND UTILITY.

DIFFERENT KINDS OF INDICATORS.

FUNCTIONS OF THE INDICATOR.

TECHNICAL TERMS EMPLOYED IN CONNECTION WITH THE INDICATOR.

HOW TO ATTACH THE INDICATOR.

MOTION OF THE PAPER ON THE DRUM OF THE INDICATOR.

Most Correct Method of Adjusting the Indicator.
Most Reliable Parts of the Steam-Engine to which to Attach the Indicator.
How to Accurately Test the Attachments of the Indicator.
The Indicator Diagram.
The Explanatory Diagram.
The Theoretic Diagram.
The Actual Diagram.
Analysis of the Diagram.
Analysis of the Diagram Simplified.
Analysis of the Diagram made Easy.
Diagrams taken from Automatic Cut-off Engines.
Diagrams taken from Throttling Engines.
Diagrams taken from Compound Engines.
Diagrams taken from Simple Engines.
Diagrams taken from Locomotives.
Diagrams taken from Condensing Engines.
Instructions for Making an Analysis of Diagrams.
Instructions how to Space the Ordinates.
The Theoretical Expansion Curve.
Application of the Theoretical Expansion Curve.
How to Draw the Theoretical Expansion Curve.
How to Locate the Theoretical Terminal Pressure.
How to Calculate the Mean Effective Pressure.

How to Calculate the Theoretical Economy by the Diagram.
How to Calculate the Theoretical Rate of Water Consumption by the Diagram.
How to Make Allowance for Cushion and Clearance.
How to Estimate the Effective Compression.
What Indicator Diagrams Show.
The Planimeter.
Steam.
Superheated Steam.
Temperature of Steam.
Volume of Steam.
Surcharged Steam.
Evaporation of Steam.
Re-evaporation of Steam.
Latent Heat of Steam.
Sensible Heat of Steam.
Heat Necessary to Generate Steam.
The Quantity of Water Necessary to Condense a Certain Quantity of Steam.
Tables of Volumes of Steam for Different Pressures.
Weight of Steam.
Effluent Velocity of Steam at Different Pressures.
Steam Worked Expansively.
Steam-Jackets.
Steam-Domes.
Steam-Jets.
Steam-Chimneys.

Relative Volume of Steam at Different Pressures.
Relative Volume of Steam to the Water from which it was Generated.
Relative Quantity of Water Required to Condense Steam.
Steam Generated from Fresh and Salt Waters.
Condensation of Steam in Steam-Cylinders and Pipes.
Quantity of Steam Required for Heating Purposes.
Steam as a Means of Putting Out Fires.
The Expansive Properties of Steam.
Steam-Engines.
Peculiarities of Design and Construction of the Engines of the Different Lines of Steamships Plying between the Different Ports of this Country and those of Other Parts of the World, with Descriptions of the Same.
Peculiarities of Design and Construction of All the Different Automatic Cut-off Stationary Engines of this Country, with Descriptions.
The Difference between Automatic Cut-off and Throttling Engines.
The Advantages of Automatic Cut-off Engines over Throttling, and Vice Versa.
The Advantages of Large Steam-Engines over Small Ones, and Vice Versa.
The Advantages of Horizontal Engines over Vertical, and Vice Versa.

The Advantages and Disadvantages of the Different Steam-Engine Cut-offs, viz., the Automatic, Positive, Adjustable, and Riding.
A Description of All the Cut-offs in Use on Stationary and Marine Engines at the Present Day.
The Advantages of Different Cut-offs over Each Other.
The Causes Most Likely to Induce some Steam-Engines to Develop Less Power than they Ought to do, while Others would Develop More.
Proportions of All the Different Engines in Use at the Present Day, according to Accurate Scale.
The Two Classes of Engines in Most General Use in the World.
The Advantages of the Condensing over the Non-Condensing Engine, and Vice Versa.
The Difference between Simple and Compound Engines, their Advantages and Disadvantages.
How the Power of any Steam-Engine may be Increased within Certain Limits.
The Quantity of Fuel it will Require to Develop a Horse-Power in Different Engines.
The Quantity of Water that will Produce a Horse-Power in the most Improved Steam-Engines, as well as the Quantity Required for those of Inferior Type.
The Difference in Point of Economy between Condensing and Non-Condensing Engines.

The Difference in First Cost, Cost of Maintenance between Condensing and Non-Condensing Engines.
The Advantages and Disadvantages of Fast and Slow Speed Engines.
Why certain Types of Engines have been Abandoned, and Others Adopted.
High-Pressure Compound Engines.
Low-Pressure Compound Engines.
Schemes for Revolutionizing the Economy of Steam-Engines.
Steam-Engine Economy.
Instructions for Placing Steam-Engines in Steamships, Tug- and Ferry-Boats.
Instructions for Setting Up, Lining, and Reversing Stationary Steam-Engines.
Rules for Estimating the Power of Steam-Engines by Formulæ, and by Indicator Diagrams.
Rules for Finding the Right Size Engine to do a Certain Amount of Work.
Rule for Finding the Size of the Cylinder for an Engine of any Power, when the Pressure and Travel of the Piston are Known.
Rule for Finding the Quantity of Steam any Engine will Require.
Rules for the Care and Management of All Classes of Steam-Engines.
Steam-Engine Governors.
Slide-Valves.
Lap on the Slide-Valve.
Lead on the Slide-Valve.

How to Tell the Amount of Lap and Lead on a Slide-Valve without Opening the Steam-Chest.
Table Showing the Amount of Lap Required for Any Desired Cut-off.
Rule for Finding the Amount of Lap Necessary for Any Desired Cut-off.
How to Set a Slide-Valve Accurately.
Friction of Slide-Valves.
Balanced Slide-Valves.
Puppet-Valves.
Double-Beat Valves.
Throttle-Valves.
Relief-Valves.
Rotary-Valves.
Semi-Rotary or Oscillating-Valves.
Basket-Valves.
Gridiron-Valves.
Valve-Gear.
Releasing Valve-Gear.
Independent Valve-Gear.
Expansion Valve-Gear.
Reversing Valve-Gear.
Whole-Stroke Valve-Gear.
Vocabulary of Technical Terms as Applied to the Different Parts of the Valve-Gear of Steam-Engines.
Stop-Cocks, Valves, and Pipes for Whatever Purpose Employed in Connection with Steam-Engines.
Bed-Plates and Housings.
Steam-Cylinders

Cylinder-Head Bolts.
Steam-Pistons.
Spring-Pistons.
Piston-Rods.
Stuffing-Boxes.
Steam- and Exhaust-Pipes.
Rock-Shafts.
Cross-Heads.
Eccentrics.
Cranks.
Crank-Pin Bearings.
Crank-Shaft Journals.
Keys, Jibs, and Straps.
Fly-Wheels.
The Link fully Illustrated and Explained.
Shifting Links
Stationary Links.
Condensers, Surface, and Jet.
Proportions of Condensers.
Advantages and Disadvantages of Different Condensers.
Relative Quantities of Water Required for the Two Methods of Condensation.
The Injector Condenser.
Korting's Jet-Condenser.
The Vacuum.
How the Vacuum is Measured.
How the Vacuum is Maintained.
How the Vacuum is Produced.
The Effect of the Vacuum.
Air-Pumps.

Capacity of Air-Pumps According to best Modern Practice.
Relative Proportion of Air-Pump Cylinders to the Cylinders of Modern Steam-Engines.
Circulating Pumps.
Different Kinds of Circulating Pumps.
Relative Proportions of Circulating Pumps.
Marine Pumps.
Wrecking Pumps.
The Saliometer.
Barometer Gauges.
Thermometers.
Marine-Engine Registers.
Spring, Mercury, Syphon, and Vacuum Gauges.
Table of Rhombs, or Points of the Compass.
Technical Terms and Definitions Used in Navigation.
Tables of Knots and Miles as Measured by Various Nations.
Table of Leagues and Miles.
Length of the Day at Different Parts of the World.
Sailing Distance in Geographical Miles from New York to Different Points on the Globe.
Latitude and Longitude of Different Places.
Marine Signals.
Marine Bell, Whistle, and Light Signals.
Railroad Signals.
Pumps.
Feed-Pumps: their Capacity, etc.
Injectors: their Capacity, Efficiency, etc.

Screw-Propellers.
The Screw as a Means of Propulsion.
Different Kinds of Screw-Propellers.
Thrust-Blocks.
Stern-Tubes.
Paddle-Wheels.
Different Kinds of Paddle-Wheels.
Comparative Efficiency of Screw-Propellers and Paddle-Wheels.
Air: its Weight, Height, Effect, etc.
Table Showing the Weight of the Atmosphere at Different Altitudes above Sea Level.
Table Showing the Force of the Wind.
Table Showing the Relative Volume of Air at Different Temperatures.
Fuel.
Different Kinds of Fuel: their Comparative Value, etc.
The Chemical Constituents of Different Kinds of Fuel.
Heat.
Effects of Heat.
Capacity of Different Bodies for Heat.
Diameters, Circumferences, and Areas of Circles.
Metals and Alloys.
Marine Boilers.
Different Kinds of Marine Boilers.
Vocabulary of Technical Terms as Applied to Different Parts of Marine Boilers.
Vocabulary of Technical Terms as Applied to Different Parts of Marine Engines.

Super-Heaters.
Feed-Water Heaters.
Funnels.
Smoke-Stacks.
Air-Casings.
Blast-Pipes.
Spanner-Guards.
Meaning of the Term Mean Effective Pressure.
Meaning of the Term Average Pressure.
Difference between Mean Effective and Average Pressure.
Difference between Boiler Pressure and Pressure per Gauge.
Difference between Boiler and Cylinder Pressures.
Causes of Decrease of Pressure between Boilers and Cylinders.
Causes why Boiler Pressures do not Represent Cylinder Pressures.
The Probable Average Pressure in any Steam-Cylinder as Compared with the Boiler Pressure.
Why Boiler Pressures Cannot be Realized in the Cylinders of Steam-Engines.
Mistakes in Employing Boiler Pressures in Estimating the Power of Steam-Engines.
Tables of Circumferences, Diameters, and Areas of Circles from $\frac{1}{64}$ to 100 Inches.
Tables of Logarithms from 0 to 1000.
Tables of Hyperbolic Logarithms.
Use of Logarithms.
Utility of Logarithms

Geometry.
Trigonometry.
Mensuration.
Navigation.
Geography.
Natural Philosophy.
Axioms.
Theorems.
Propositions.
Solutions.
Corollaries.
Tables of Squares, Cubes, and Cube-Roots of Numbers from 1 to 1000.
Meaning of the Term "Cubed."
Meaning of the Term "Squared."
Meaning of the Term "Quotient."
Meaning of the Term "Product."
Addition.
Subtraction.
Multiplication.
Division.
Proportion.
Common Fractions.
Decimals.
Triangles.
Equilateral.
Isosceles.
Scalene.
Acute.
Obtuse.
Right Angle, etc.

The Centennial Corliss Engine.
Wright's Automatic Cut-Off Engine.
The Woodbury, Booth & Pryor's Automatic Cut-Off Engine.
Double-Slide Valves.
Semi-Rotary Valves.
The Brown Automatic Cut-Off Engine.
The Harris Corliss Engine.
Marine Engines.
Modern Marine Compound Engines.
Sections of Marine Compound Engines.
Section of Slide-Valve Engine.
The Woodruff & Beach Automatic Cut-Off High-Pressure Engine.
Expansion Gears.
The Putnam Machine Company's Automatic Cut-Off Engine.
The Green Automatic Cut-Off High-Pressure Engine.
The Douglass Automatic Cut-Off Engine.
The Babbitt & Harris Steam-Piston.
Piston, Connecting-Rod, and Crank-Connection.
The Reynolds Corliss Engine.
The Crank.
The Link.
Valve-Gears.
The Watertown Automatic Cut-Off Engine.
The Waters Governor.
The Shive Governor.
Reversing-Gear for Steam-Engines.
Diagrams of Slide-Valve.

Wheelock's Automatic Cut-Off Engine.
Section of the Cylinder, Piston, Steam- and Exhaust-Valves of Wheelock's Automatic Cut-Off Engine.
Poppet Valves.
Slide-Valves.
The Wells Two-Piston Balance-Engine.
Section of the Wells Two-Piston Balance-Engine.
The Wardwell Valveless Engine.
The Steam-Engine Indicator.
Section of the Indicator.
Thompson's Indicator.
Richards' Parallel Motion Indicator.
The Atlas Corliss Engine.
Indicator Diagrams.
The Planimeter.
Diagram Measured by the Planimeter.
The Porter-Allen High-Speed Engine.
End View of a Surface Condenser.
The Injector Condenser.
Independent Condenser and Air-Pump.
Independent Air- and Circulating-Pump, with Air-Pump at one End, Circulating-Pump at the Other, and Steam-Cylinder in the Middle.
Section of Marine Air-Pump.
Independent Marine Circulating-Pump.
Marine Wrecking-Pump.
The Salinometer.
The Hotwell Thermometer.
The Uptake Thermometer.

Marine Steam-Engine Register.
Spring Steam-Gauges.
Marine Whistle Signals.
Marine Light Signals.
Marine Bell Signals.
Railroad Signals.
Pumps.
William Sellers & Co.'s Lifting Injectors.
Section of William Sellers & Co.'s Lifting Injector.
Rue's "Little Giant" Injector.
Friedman's Injector.
The Keystone Injector.
The Eclipse Injector.
The Clipper Adjustable Injector.
Section of Clipper Injector.
Mack's Fixed-Nozzle Injector.
The Inspirator.
The Ejector or Lifter.
Jamison's Steam Water-Ejector.
Water-Tubular Marine-Boiler.
Fire-Tubular Marine-Boiler.
Direct Flue and Return Tubular Marine-Boiler.
Method of Bracing Marine Steam-Boilers.
The Buckeye Automatic High-Pressure Cut-Off Engine.
Diagrams of Circles.
The Wetherill Corliss Engine.
Diagram of Steam-Joints.
The Fitchburg Steam-Engine.
The Fitchburg Governor.

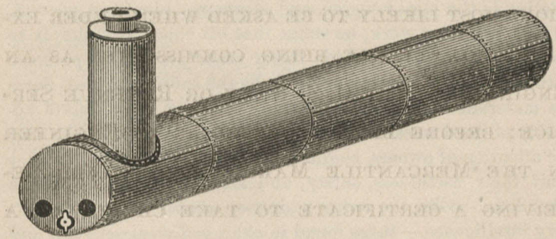
The Engineer's Handy-Book contains nearly 300 Main Subjects, 1316 Paragraphs, 876 Questions and Answers, 52 Suggestions and Instructions, 105 Rules, Formulæ, and Examples, 149 Tables, 195 Illustrations, 31 Indicator Diagrams, and 167 Technical Terms; over 3000 different Subjects, with the Questions most likely to be asked when under examination, before being commissioned as an Engineer in the U. S. Navy or Revenue Service; before being licensed as an Engineer in the Mercantile Marine Service, or receiving a certificate to take charge of a steam-engine or boiler in locations where such certificate is necessary. There is not a subject within the whole range of steam-engineering on which it does not treat.

With a great variety of other information not to be found in any other book ever published on the same subject in this country or in Europe, and more fully illustrated than any other work ever published on this subject.

USE AND ABUSE

OF

THE STEAM-BOILER.



BY

STEPHEN ROPER, Engineer,

Author of

"Roper's Catechism of High-Pressure or Non-Condensing Steam-Engines," "Roper's Hand-Book of the Locomotive," "Roper's Hand-Book of Land and Marine Engines," "Roper's Hand-Book of Modern Steam Fire-Engines," "Roper's Handy-Book for Engineers," "Roper's Improvements in Steam-Engines," "Questions for Engineers," etc.

PHILADELPHIA:
EDWARD MEEKS.

Diameter and Length of Steam-boilers and Thickness of Boiler-plate
Evaporation in Steam-boilers
Evaporative Efficiency of Steam-boilers
Clapp and Jones' Vertical Circulating Tubular Boiler
Methods of Testing the Evaporative Efficiency of Steam-boilers
Proportion of Grate Surface to Heating Surface
Internal and External Corrosion of Steam-boilers
Internal Grooving in Steam-boilers
Silsby's Vertical Tubular Boiler
Expansion and Contraction of Boilers
Heating-surface of Steam-boilers
Rules for finding the Heating-surface of Steam-boilers
The Latta Steel Coil-boiler
Horse-power of Steam-boilers
The Moorhouse Safety Sectional Boiler
Setting Steam-boilers
Testing Steam-boilers
Repairing Steam-boilers
Neglect of Steam-boilers
The Wiegand Sectional Boiler
Safe Working Pressure of Steam-boilers
Table of Safe Internal Pressures for Steel Boilers.
Table of Safe Internal Pressures for Iron Boilers.
The Roger's and Black Boiler
Selection of Steam-boilers.
Pulsation in Steam-boilers
Pierce's Rotary Tubular Boiler

Location of Steam-boilers
The Harrison Boiler
Boiler-flues
Table of Squares of Thickness of Iron, and Constant Numbers to be used in finding the Safe External Pressure for Boiler-flues
Table of Safe Working External Pressures on Flues 10 Feet long
Table of Safe Working External Pressures on Flues 20 Feet long
Collapsing Pressure of Wrought-iron Boiler-flues ¼ Inch thick
Collapsing Pressure of Wrought-iron Boiler-flues $\frac{5}{16}$ Inch thick
Collapsing Pressure of Wrought-iron Boiler-flues ⅜ Inch thick
Collapsing Pressure of Wrought-iron Boiler-flues $\frac{7}{16}$ Inch thick
The Shapley Boiler
Boiler Tubes
The Phleger Boiler
Tables of Superficial Areas of External Surfaces of Tubes of Various Lengths, Diameters in Square Feet
Table of Superficial Areas of Tubes of different Lengths and Diameters from 2½ to 3 Inches and from 8 to 20 Feet
Steam-boiler Connections and Attachments .
Gauge-cocks
Steam-gauges
Glass Water-gauges
The Babcock and Wilcox's Sectional Steam-boiler

SAFETY-VALVES
Table showing the Rise of Safety-valves, in parts of an Inch at different Pressures
Table of Comparison between Experimental Results and Theoretical Formulæ
RULES
WITTINGHAM'S TUBULOUS BOILER
FOAMING IN STEAM-BOILERS
INCRUSTATION IN STEAM-BOILERS
PREVENTION AND REMOVAL OF SCALE IN STEAM-BOILERS
STEAM-BOILER EXPLOSIONS
EXPERIMENTAL BOILER EXPLOSIONS
THE ROOT BOILER
VAGARIES OF EXPERTS IN REGARD TO STEAM-BOILER EXPLOSIONS
DEFECTS IN THE CONSTRUCTION OF STEAM-BOILERS.
IMPROVEMENTS IN STEAM-BOILERS
THE ALLEN BOILER.
CARE AND MANAGEMENT OF STEAM-BOILERS.
INSTRUCTIONS FOR FIRING
DAMPERS
STEAM-BOILER INSPECTION
Rules for finding the Quantity of Water which Boilers and other Cylindrical Vessels are capable of Containing
EFFECTS OF DIFFERENT KINDS OF FUEL ON STEAM-BOILERS
BOILER MATERIALS
STEEL
STRENGTH OF IRON BOILER-PLATE
DEFINITIONS AS APPLIED TO BOILERS AND BOILER MATERIALS

PUNCHED AND DRILLED HOLES FOR BOILER SEAMS.
Table showing the Strength of Welded Boiler-plates
PATENT BOILERS
THE GALLOWAY BOILER
STRENGTH OF RIVETED SEAMS
COMPARATIVE STRENGTH OF SINGLE- AND DOUBLE-RIVETED SEAMS
HAND- AND MACHINE-RIVETING
COUNTER-SUNK RIVETS
RIVETS
Table showing Diameter and Pitch of Rivets for different Thicknesses of Plate
STRENGTH OF STAYED AND FLAT BOILER SURFACES
BOILER-STAYS
STAY-BOLTS
CALKING
TESTING-MACHINES
FEED-WATER HEATERS
Table showing the Units of Heat required to Convert One Pound of Water, at the Temperature of 32° Fah., into Steam at different Pressures
GRATE-BARS
CHIMNEYS.
Table showing the Proper Diameter and Height of Chimney for any kind of Fuel
Table showing Heights of Chimneys for producing certain Rates of Combustion per Square Foot of Area of Section of the Chimney
SMOKE
CONTRIVANCES FOR INCREASING DRAUGHT AND ECONOMIZING FUEL IN BOILER FURNACES

Table showing the Actual Extension of Wrought-iron at various Temperatures . . . . .
Table showing the Linear Dilatations of Solids by Heat . . . .
Table deduced from Experiments on Iron Plates for Steam-boilers, by the Franklin Institute, Philadelphia . . . .
Table showing the Results of Experiments made on different Brands of Boiler Iron at the Stevens Institute of Technology, Hoboken, N. J. . .
Table showing the Weight of Cast-iron Balls from 3 to 13 Inches in Diameter. . . . . .
Table showing the Weight of Cast-iron Plates per Superficial Foot as per Thickness . . . .
Table showing the Weight of Round-iron from ½ an Inch to 6 Inches Diameter, One Foot Long.
Table showing the Weight of Boiler-plates One Foot Square and from $\frac{1}{16}$th to an Inch Thick .
Table showing the Weight of Square Bar-iron from ½ an Inch to 6 Inches Square, One Foot Long .
Table showing the Weight of Cast-iron Pipes, One Foot in Length, from ¼ Inch to 1¼ Inches Thick, and from 3 to 24 Inches Diameter. .
Table showing the Tensile Strength of various Qualities of American and English Cast-iron .
Table showing the Tensile Strength of various Qualities of American Wrought-iron. . .
Table showing the Tensile Strength of various Qualities of English Wrought-iron
To Polish Brass . . . . .
Cement for making Steam-joints
Steam-dampers
Index

elaborate description of all Modern Steam Fire-Engines, Boilers, and Fire-Pumps, and is free from formulæ or ultra mathematical expressions. Fourth Edition. 16mo, tuck, gilt edge, $3.50.

Roper's Engineer's Handy-Book. Containing a full explanation of the Steam-Engine Indicator, and its use and advantages to Engineers and Steam Users; with formulæ for estimating the power of all classes of Steam-Engines; also, Facts, Figures, Questions and Tables for Engineers who wish to qualify themselves for the United States Navy, the Revenue Service, the Mercantile Marine, or to take charge of the better class of Stationary Steam-Engines. With Illustrations. Fourth Edition, Revised and Enlarged. By STEPHEN ROPER, Engineer. $3.50.

Roper's Use and Abuse of the Steam-Boiler, including its Care and Management. With Illustrations. This is the only book ever published in this country devoted exclusively to Steam-Boilers. It contains illustrations of all the different kinds of Steam-Boilers now in use, whether Stationary, Locomotive, Fire, or Marine; and also of Sectional or Patent Boilers. By STEPHEN ROPER, Engineer. Eighth Edition. 18mo, tuck, gilt edge, $2.00.

Roper's Questions and Answers for Engineers. This little book contains all the Questions that Engineers will be asked when undergoing an examination for the purpose of procuring licenses to run either Stationary, Locomotive, or Marine Engines and Boilers. By STEPHEN ROPER, Engineer. $3.00.

Roper's Simple Process for Estimating the Horse-Power of Steam-Engines, from Indicator Diagrams, or the work an engine was performing at the time the diagram was taken. One of the most important devices ever employed in connection with the Steam-Engine. 50 cents.

Roper's Instructions and Suggestions for Engineers and Firemen. This little book is made up of a series of suggestions and instructions, the result of recent experiments and the best modern practice in the care of Steam-Engines and Boilers. It is brimful of just such information as persons of limited education having charge of steam machinery need. It is written in plain, practical language, devoid of theories or mathematical formulæ. $2.00.

Roper's Care and Management of the Steam-Boiler. One of the most practical works ever published on this subject, as it embraces the following subjects: Care and Management of Steam-Boilers, Horse-Power of Steam-Boilers, Repairing Steam-Boilers, Incrustation in Steam-Boilers, Steam-Boiler Explosions, Testing Steam-Boilers, Externally and Internally Fired Steam-Boilers, Design of Steam-Boilers, Steam-Boiler Materials, Mud-Drums, Steam-Domes, Cleaning Steam-Boilers, Different Types of Steam-Boilers, Feed-Water Heaters, Fuel, Chimneys (area and height), Draught, Smoke, Instructions for Firing, Comparative Efficiency of Different Types of Steam-Boilers, with a great amount of other information of immense value to owners of Steam-Boilers, Engineers, and Firemen, expressed in plain, practical language. $2.00.

Roper's Young Engineer's Own Book, containing an explanation of the Principle and Theories on which the Steam-Engine as a Prime Mover is based; with a description of different kinds of Steam-Engines, Condensing and Non-Condensing, Marine, Stationary, Locomotive, Fire, Traction, and Portable; together with Instructions how to Design, Proportion, Locate, Repair, Reverse, and Run all Classes of Steam-Engines, with Tables and Formulas for finding their Horse-Power; also, Suggestions on the Selections, Care, and Management of all Classes of Steam-Engines, Boilers, Pumps, Injectors, etc., for the Use of Educational Institutions where students are intended to engage in Mechanical Pursuits, and for the Private Instruction of Youths who show an Inclination for Steam-Engineering. With 106 illustrations. By STEPHEN ROPER, Engineer, Author of Roper's Practical Hand-Books for Engineers and Firemen. Second Revised Edition. 16 mo., tuck, gilt edge, $3.00.

Bilgram.—Slide-Valve Gears. A new graphical method for Analyzing the Action of Slide-Valves, moved by eccentrics, link-motion, and cut-off gears. By HUGO BILGRAM, M.E. 16mo, cloth. $1.00.

Cooper.—A Treatise on the use of Belting for the Transmission of Power. With numerous illustrations of approved and actual methods of arranging Main Driving and Quarter Twist Belts, and of Belt Fastenings. Examples and Rules in great number for exhibiting and calculating the size and driving power of Belts. Plain, Particular, and Practical Directions for the Treatment, Care, and Management of Belts. Descriptions of many varieties of Beltings, together with chapters on the Transmission of Power by Ropes; by Iron and Wood Frictional Gearing; on the Strength of Belting Leather; and on the Experimental Investigations of Morin, Briggs, and others. Second Edition. By JOHN H. COOPER, M.E. 1 vol., demy octavo, cloth. $3.50.

Grimshaw.—Saws. The History, Development, Action, Classification, and Comparison of Saws of all kinds. With Appendices. Concerning the details of manufacture, setting, swaging, gumming, filing, etc. Care and use of saws. Tables of gauges. Log measurements. Lists of saw patents and other valuable information. Second Edition, with Supplement. Profusely Illustrated. By ROBERT GRIMSHAW. Quarto, cloth. $4.00.

Overman.—Mechanics for the Millwright, Engineer, Machinist, Civil Engineer, and Architect. By FREDERICK OVERMAN. 12mo, cloth. 150 illustrations. $1.50.

Riddell.—The Carpenter and Joiner Modernized. Third Edition, revised and corrected, containing new matter of interest to the Carpenter, Stair-Builder, Carriage-Builder, Cabinet-Maker, Joiner, and Mason; also explaining the utility of the Slide Rule, lucid examples of its accuracy in calculation, showing it to be indispensable to every workman in giving the mensuration of surfaces and solids, the division of lines into equal parts, circumferences of circles, length of rafters and braces, board measure, etc. The whole illustrated with numerous engravings. By ROBERT RIDDELL. 4to, cloth. $7.50.

Riddell.—The New Elements of Hand Railing. Revised Edition, containing forty-one plates, thirteen of which are now for the first time presented, together with the accompanying letter-press description. The whole giving a complete elucidation of the Art of Stair-Building. By ROBERT RIDDELL, author of "The Carpenter and Joiner Modernized," etc. One volume, folio. $7.00.

Any of the above works will be sent to any part of the United States or Canada on receipt of list price.

Send money in Registered Letter, P. O. Order, or Postal Note.

EDWARD MEEKS, Publisher,

No. 1012 Walnut Street,

PHILADELPHIA, PA.