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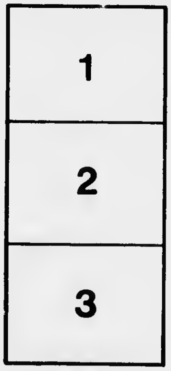

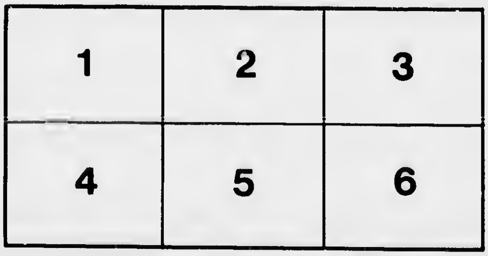

MANUAL

OF

ENGINEERS' CALCULATIONS.

D. McLAUGHLAN SMITH.

Cam: Smith, 745.

D. McLaughlan.

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HELIOTYPE PRINTING CO., BOSTON, MASS.

745.

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BY

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AFFECTIONATELY DEDICATED

TO

MY FATHER,

WILLIAM MORGAN SMITH.

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PREFACE.

THE AUTHOR, after many solicitations from engineers, has been persuaded to publish this book, giving to the public, now, the subject-matter taught by him for years to his pupils, of engineering, having for several years been teacher of engineers' calculations at St. John, N. B.

This work is intended for the use of engineers desirous of passing the Board of Steamboat Inspection to obtain certificates of competency, and is drawn up with a view to self-instruction. It contains the rules for working and answering the kind of questions usually presented to candidates, with drawings, diagrams and specimen examination papers; also much miscellaneous matter of interest to engineers, containing notes, extracts, questions, calculations and tables.

In any book on the steam engine, or pertaining thereto, there can be little originality, so many have written on the subject, and the Author is, of course, indebted to many sources for his information. Still, there are many rules, explanations, and other matter, regarding the examination for a Canadian certificate, that has never been published before, besides many of the Author's own rules, articles and methods.

For the benefit of those who desire to become more fully informed as to all that pertains to steam engineering, I have given a selected list of works useful for study.

St. John, 1st November, 1886.

D. McL. S.

MANUAL OF ENGINEERS' CALCULATIONS.

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NOTE.—Pages in reference to the "S. B. Inspection Act (1882) of Canada" refer to the official issue of that "Act," but may be found in this volume by the number of section when given or known:

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THE QUALIFICATIONS THAT EVERY ENGINEER SHOULD HAVE.

HE should be able to write a good legible hand and understand the first five rules of arithmetic thoroughly, decimals, decimal fractions; also fractions, proportion, square root, cube root, Euclid and drawing.

He should understand the construction, principle and use of such instruments as Bourdon steam, vacuum and water gauges, thermometer, barometer, and the salinometer.

He should thoroughly understand incrustation and corrosion, their cause, effect and remedy, also the principal causes of boiler explosions, and the effect of water making steam when suddenly liberated from a high pressure.

He should have a knowledge of how repairs are made to engine and boiler, in cases of emergency, or when laid up for the season.

He should understand the use of indication, its principles, and the method of taking cards, and the means of calculating them, also the meaning of the diagrams.

He should understand valve-motion and how to explain the same by means of drawing diagrams.

He should be conversant with surface condensation, and the working of steam expansively.

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AIR.

AIR is a mechanical mixture of nitrogen and oxygen gases. It was considered by the ancients that air had neither weight nor elastic force.

One of the earliest inventions of Ctesibius, the teacher of Hero, was the pump; and it soon came into general use; and those accustomed to them soon noted the fact that water rose above its ordinary level in the pump tube when the bucket had withdrawn the air from that part. Galileo's reflections soon led him to the conclusion that air had weight, and to his pupil Torricelli was the honor due of constructing the barometer and of finding out the relative weight of air.

Air has both weight and force, pressing in every direction, in the ratio of 2,124 lbs. per square foot of surface. Many attempts have been made to bring the elastic force of the atmosphere into use like steam.

Pascal first applied the barometer to the measuring of the heights of elevated places, on the theory that the pressure of air diminishes as we ascend, thereby causing the mercury to fall.

The action of the barometer is regulated by the weight of the air, which is heaviest during serene, settled, or frosty weather, or when contrary winds blow it toward any locality. It is lightest when saturated with vapor to the rainy point, or when contrary winds blow it away from any locality. In northern climates the variations are greatest.

The atmospheric air that surrounds us contains the oxygen that is necessary to life, in a diluted condition of one-fifth of oxygen to four-fifths of nitrogen.

An ordinary iron furnace is estimated to require 310 tons of air in twenty-four hours, or enough for 20,000 men.

That it is oxygen gas of air that is consumed in supporting ordinary combustion may be shown by covering a candle, lighted, in a bell glass, with the lower edge of the glass resting in water to prevent a further supply of air getting inside the glass, and as the enclosed oxygen of the air is consumed (the enclosed oxygen being exhausted) the flame grows less and less until it goes out, and the contents of the glass are found to be nitrogen (apparently unaltered), hydrogen and carbonic acid.

One cubic foot of air, at 32° F., weighs 1.29 ounces. Air rushes into a void with the velocity a heavy body would acquire by falling in a homogeneous atmosphere. Air is eight hundred and forty times lighter than water. The atmosphere supports water at thirty-three feet; homogeneous atmosphere, therefore, $33 \times 840 = 27,720$ feet.

A heavy body falling one foot acquires the velocity of eight feet per second.

Velocities are as the square-roots of their heights; therefore to find the velocity corresponding to any given height, expressed in feet per second, multiply the square root of the height in feet by eight.

For air we have $V = \sqrt{27,720} = 166,493 \times 8 = 1,332$ feet per second. This, therefore, is the velocity with which common air would rush into a void, or, 79,920 feet per minute; some say 80,880 ditto.

The thermometer, when first invented, about two hundred years ago, air, spirits of wine, and oil were made use of; but all these have given way to quicksilver.

Fahrenheit is used in England; Reaumur and the Centigrade thermometers on the continent. The thermometer is on the principle of the expansion and contraction of quicksilver. Plunge it into boiling water, it stands at 212°, and 32° denotes the freezing-point. Between these the space is divided into 180.

Zero (0) is extremely cold; 32° freezing-point; 55° for temperate heat; 76° summer heat; 98° blood heat; 112° fierce heat; 176° spirits of wine boils; 212° water boils; $\frac{1}{10}$ of an inch in a yard is $\frac{1}{2520}$ for 90° Fahrenheit.

Mercury is fourteen times heavier than water; therefore, if the pressure of the atmosphere will balance thirty-four feet of water, it will only balance $\frac{1}{14}$ part of that height of mercury, viz., a little more than twenty-nine inches.

In the barometer, if the air be dense, the mercury rises in the tube and indicates fine weather; if the air becomes lighter the mercury falls and indicates rain. Standard altitude in England varies between twenty-eight and thirty-one inches; the difference is called the state of variation.

WATER.

STEAM, to be understood, requires a knowledge of water and heat; in the present paper, the first will be considered.

Water, in its ordinary state, is a fluid; it occupies the greatest part of our globe and performs most important duties; it is also found in a combined state in animal and vegetable nature. Chemically considered, an ordinary man would be about made up of one hundred and five pounds of water and thirty-five pounds of carbon and nitrogen, and that five-sixths of his daily food is water.

One volume of oxygen and two volumes of hydrogen, or, by weight, one part of hydrogen and eight parts of oxygen, are required to form water.

Water is thirty times heavier than oxygen gas, four hundred and seventy-eight times heavier than hydrogen, and thirty-four times heavier than air.

Water freezes at 32° F., when its expansive force is exhibited. The expansive power of water is supposed to be derived from the re-arrangement of crystallizing particles in an angle of 60°, or 120° to each other, requiring more space than when in a fluid state, and thus resisting confinement.

Water, being almost incompressible, is made to develope great power, as in Bramah's hydraulic presses, and the hydraulic ram, whereby the strengths of cables, anchors, iron, and other materials are tested, and other operations performed that require force.

Water is the standard of comparison of weights of other liquids and solids; a cubic foot of water weighs one thousand ounces and the Imperial gallon one hundred and sixty ounces, or ten pounds.

In pounds, the weight of a cubic foot of water is sixty-two and one-half pounds, and the cubic contents in feet of any water-tank, or boiler, multiplied by sixty-two and one-half, given the weight of water required to fill it, and this divided by ten gives the number of gallons. There are 62.355 gallons of water in one cubic foot.

By knowing the particulars of the impurities in a certain water, the practical engineer can decide with confidence whether it is or is not desirable to employ any chemical agent, such as oxalic acid, carbonate of potash, or soda, to precipitate, or nitric, muriatic or acetic acid, to hold in solution and pass through with the steam some of these impurities; but the agents should be used with much caution.

To find the measure of a column of water in pounds, if the base be circular, take the diameter in inches, the height in feet; square the diameter in inches and multiplying by the decimal .341, or by 34, this gives the weight of one foot in height; therefore, multiplying by the number of feet in height gives the pounds.

If the base be square, multiply by the decimal .434; in great works, take the area of the base in feet, multiply by 62.5 if square, and if circular 49.0875 and that by the height in feet.

HEAT.

THERMOMETER is the instrument used to measure heat, and the degree of the temperature is indicated by a scale of equal degrees, and the distance between freezing and boiling points is by Fahrenheit divided into 180 parts, and by Celcius Centigrade scale into 100 parts; the first is mostly used for ordinary purposes and the other for scientific subject.

Heat is communicated by direct contact, or conduction by right lines, or radiation, and by carrying, or convection.

An English heat unit is that which is required to raise the temperature of one pound of water one degree Fahrenheit, the expenditure of heat is the same whether two pounds of water be raised one degree, or one pound of water be raised two degrees.

The English unit of work, which consists of the sustained exertion of pressure through space, is one foot-pound ; that is, a pressure of one pound exerted through a space of one foot.

The unit of heat, then, is capable of raising seven hundred and seventy-two pounds weight one foot high, and its mechanical equivalent is expressible by seven hundred and seventy-two foot-pounds; then one English thermal unit, or one degree, or one degree Fahrenheit, in one pound of water, 772 foot-pounds; one degree Centigrade in one pound of water, 1,389 foot-pounds. A French thermal unit is nearly equal to four English thermal units ; 1. to 4.

Theory of all gases, or vapors, is that of atoms moving or vibrating in all ways, with rapidity and pressure, being the impact of the numerous atoms striking against the sides of the vessel containing the gas and vapor.

When the piston in the cylinder yields to the pressure of steam, the atmosphere rebounds from it with the same velocity with which they strike, but will return after each succeeding blow, with a velocity continually decreasing as the piston continues to recede, and so the temperature diminishes. Water descending seven hundred and seventy-two feet acquires a velocity of two hundred and twenty-three feet per second, and if suddenly brought to rest when moving with this velocity it would be violently agitated and would be raised one degree of temperature.

COMBUSTION.

Combustion is one of the many sources of heat, and it denotes the combination of a body with any of the substances termed supporters of combustion; with reference to the generation of steam, we may say we are restricted to oxygen, because of the small quality of hydrogen in fuel. All bodies when intensely heated become luminous; when the heat is produced by combination with oxygen they are said to be ignited, and when the body heated is in a gaseous state it forms what is termed flame.

Carbon exists in nearly a pure state in charcoal and in soot. In its combustion one pound of it produces sufficient heat to increase the temperature of 14,500 pounds of water one degree.

The volatile products of the combustion of coal are hydrogen and carbon, the union of which in the furnace are olefiants gases; which upon combining with air become carbonic acid, or carbonic oxide, etc.

Carbonic oxide is the result of imperfect combustion and carbonic acid that of perfect combustion.

One (1 lb.) pound of carbon combines with 2.66 pounds of oxygen and produces 3.66 pounds of carbonic acid gas.

Smoke is the combustible and incombustible products evolved in the combustion of fuel which pass off by the flue of a furnace, and it is composed of such portions of the hydrogen and carbon of the fuel gas as have not been supplied or combined with oxygen, and consequently have not been converted either into steam or carbonic acid; the hydrogen loses its gaseous character and returns to its elementary state of a black body and as such becomes visible.

Bituminous portion of coal is converted into the gaseous state alone; the carbonaceous portion not in the solid state. It is partly combustible and partly incombustible.

To effect the combustion of one cubic foot of oxygen is required, ten feet of atmospheric air are necessary to supply this quantity of oxygen.

An insufficient supply of air causes imperfect combustion, an excessive supply a waste of heat and fuel.

MECHANICAL EQUIVALENT OF HEAT.

The mechanical equivalent of heat is the quantity of heat required to raise the temperature of one pound of water one degree, or will raise seven hundred and seventy-two pounds one foot high ; or the weight of one pound descending seven hundred and seventy-two feet is equal to one degree of heat.

Then, seven hundred and seventy-two foot-pounds is what is called the mechanical equivalent of heat, the number expresses the whole work due to the quantity of heat which is able to raise one pound of water one degree of heat.

Heat is a peculiar motion of the particles which prevents their contact. Heat and mechanical power are convertible forces. The force of the heat that raises one pound of water one degree F. will lift a weight of seven hundred and seventy-two pounds one foot high. The power of a weight of seven hundred and seventy-two pounds descending one foot if applied to a small paddle-wheel turning in one pound of water, will by friction, raise the temperature of the water one degree Fahrenheit. A heat unit is the amount of heat that raises a pound of water 1°F. or that lifts a weight of seven hundred and seventy-two pounds one foot high.

Then, seven hundred and seventy-two foot-pounds equals one heat unit—one heat unit equals seven hundred and seventy-two foot-pounds.

COAL HEAT AND COMBUSTION.

HEAT is stored up in coal, and is liberated from it by combustion; that is, the burning of coal, which consists of carbon, hydrogen, nitrogen, sulphur, oxygen and ashes; and they have a relative proportion, in different averages, but all having carbon as its, or their, principal part; now let us chemically consider what these elements are that compose coal: 1st. Carbon, which is an extremely important and very abundant element; all organic substance, all things which have life contain it. In the mineral kingdom coal (containing 70 to 85 per cent.) and its different and various forms, also limestone, chalk, marble, etc. All vegetable life is directly dependent upon the presence of the compound of carbon, carbonic acid, which exists in the atmosphere. Carbon is divided into three distinct modifications, namely, (1) the diamond; (2) plumbago, or graphite; (3) ordinary charcoal or lamp-black; of this last there are many sub-varieties. In each of the above forms carbon is an infusible, non-volatile, solid, devoid of taste and smell, and in whatever they may differ they all agree in this: that on being strongly heated in the presence of oxygen they unite with it and form the same compound, an oxide of carbon (CO^2.)

Coke and anthracite coal are impure sub-varieties of carbon, which from a chemical point of view may be classed either with the graphites or charcoals, or still better between them. Coke is the residue resulting from the destructive distillation of soft (bituminous) coal, as in the manufacture of illuminating gas.

Bituminous coal is a substance of vegetable origin which appears to have been formed from plants by a process of slow decay going on without access of air and under the influence of heat, moisture and great pressure. Like vegetable matter, in general, it is composed of carbon and hydrogen together with small proportions of oxygen and nitrogen and a certain quantity of earthy and saline substances commonly spoken of as inorganic matter. On being heated in the air it burns away almost completely, after awhile leaving nothing but the inorganic components as ashes. But when heated out of contact with the air, that is to say, when subjected to a destructive distillation, the volatile hydrogen is all driven off in combination with some of carbon, either as a gas or as a tarry liquid, and the residue, or coke, contains only carbon contaminated with inorganic matter of the coal.

Anthracite or hard coal is supposed to have been formed like soft coal from slow decay of vegetable matter and then to have been subjected to some sort of natural distillation by which it has been deprived of all the hydrogen, nitrogen and oxygen of the original wood. It is thus a coke formed by natural agencies.

Oxygen is the most widely spread and most important of all the elements; was discovered by Priestly and Scheele 1774. It constitutes one-fifth of the atmosphere, eight-ninths of the weight of water, and at least one-third of the materials composing the solid crust of the earth; it is a tasteless, colorless, inodorless gas.

Combustion is simply chemical combination, and when the combination is violent, sufficient heat is developed to produce fire: the affinities of oxygen are remarkably strong, and it is capable of entering into combination with everything in nature except Flourine; therefore fire is generally oxygen entering into combination with the body burning.

In the fires in our houses the oxygen of the air is combining with the coal, which is carbon, to form an invisible gas, carbonic acid gas, which passes up the chimney; hence, we say that oxygen is the great supporter of combustion; of course combustion will be more violent in pure gas than in the air when it is diluted with nitrogen.

Nitrogen is the chief element of the air of which it forms four-fifths. From being an element of nitric acid, Chatal gave the gas the name of azote from its inability to support life. It exists in almost all vegetable and animal nature.

The simplest method of preparing nitrogen is to deprive air of its oxygen by passing it through a porcelain tube containing copper turnings which is surrounded by red-hot charcoal. The heated copper combines with the oxygen and the nitrogen is received in a gas-holder.

Sulphur is a yellow mineral, solid, which burns with a blue flame, giving off suffocating fumes, and is found mixed with the soil in many volcanic districts; it also appears in combination with metals, etc., forming a large class of ores named sulphides.

Sulphur is brittle, without taste or smell in its native state, but when rubbed emits a peculiar odor.

The following is a proportional representative table of the amount of each element contained in coal:

Name of Element.	NAME OF COAL.				
	Welsh.	Lancashire.	Newcastle	Scotch.	The Mean.
Carbon	85	80	81	78	81
Hydrogen	5	5	$5\frac{1}{2}$	$5\frac{1}{2}$	$5\frac{1}{2}$
Nitrogen	1	1	$1\frac{1}{2}$	$1\frac{1}{2}$	1
Sulphur	1	2	2	1	$1\frac{1}{2}$
Oxygen	3	7	6	$9\frac{1}{2}$	$6\frac{1}{4}$
Ash	5	5	4	$4\frac{1}{2}$	$4\frac{3}{4}$
	100	100	100	100	100

The air (which is composed of oxygen and nitrogen mixed in the proportion of four measures of N. to one of O.) must be mixed with coal before it will burn, that is, the oxygen of the air mixes with the carbon, etc., of the coal, also in the proportion of one hundred and fifty cubic feet of air for every pound of coal, but in practice it is usually found that twice this is required, or say one pound of coal for eighteen pounds of air.

The hydrogen gives out part for part of heat, but as there is so much more carbon than hydrogen in coal we get the greater amount of heat from that carbon, but not proportionally. The coal fields of the United States are the largest known, embracing an area more than double that of Great Britain. These immense deposits lie chiefly within the western slopes of the Alleghany region, West Pennsylvania, Ohio, Virginia, and in the peninsular tract of country between the great lake basins of Michigan, Huron and Erie, and in the region extending across the Missouri and Arkansas Rivers, etc.

These vast stores of coal are but little worked, however, and the produce of the United States is nothing like that of Great Britain. In Canada the laurentian and siluvian deposits forming the chief part of the river valley of the St. Lawrence, show the appearance of coal, but New Brunswick and Nova Scotia, both now included in Canada, have worked mines, and on the other side coal of an excellent quality is procured in the Island of Vancouver, of the Province British Columbia; coal has also been found in the Northwest Territory of Canada, along the valley of the Saskatchewan River, also along the McKenzie River of the North.

TABLE OF PRODUCTION OF COAL IN DIFFERENT COUNTRIES DURING SEVERAL YEARS.

Name Country.	Year 1870. Tons.	Year 1871. Tons.	Year 1875. Tons.	Year 1880. Tons.	Year 1881. Tons.
Great Britain..... Ireland........... }	112,000,000	117,352,028	131,867,105	....	....
United States..	28,000,000				....
Germany	26,744,000	....	....	63,500,000	....
France...............	13,509,000	....	....	42,161,000	....
Belgium	12,943,000	....	....	18,825,000	....
Austria..	4,100,000	....	....	14,000,000	....
Russia	588,000	....	....	6,000,000	....
Spain..................	550,000	....	....	2,200,000	....
Canada...............	....	....	....	750,000	....
				1,032,713	1,338,391

The probable quantity of coal in the coal fields of the United Kingdoms is about 146,480 millions of tons, of this 90,207 millions of tons in fields and probable exists under the (permian) and other superincumbent strata 56,273 millions of tons.

Some give the probable period of the exhaustion of these fields, etc., at two hundred years from the present time.

THE RELATIVE VOLUME OF STEAM AND WATER.

THE relative volume of steam is the quantity of steam generated from a given quantity of water divided by that water, etc.

Again, the relative volume of steam is the quotient of the absolute volume of the steam by the corresponding volume of water.

The weight of a cubic foot of steam at various temperatures is obtained by dividing $62\frac{1}{2}$ pounds, the weight of a cubic foot of water, by its relative volume.

A cubic inch of water under an ordinary atmospheric pressure is converted into 1700 cubic inches of steam, or in a unit of measure nearly one cubic foot, and it exerts a mechanical force equal to the rising of 2120.14 pounds one foot high.

Steam rising from water at its boiling point is equal to the pressure of the atmosphere, which is 14.7 pounds.

The velocity of steam when flowing into a vacuum is about 1550 feet per second, that, at an expansive power, equal to the atmosphere. When at ten (10) atmospheres the velocity is increased to but 1780 feet per second, and when flowing into air under a similar pressure, is about 650 feet per second, increasing to 1600 per second for a pressure of twenty atmospheres.

The volume of a cubic foot of water when evaporated into steam is 1700 cubic feet; then

$1 \div 1700 = .00058823$, the density or specific gravity of steam at the pressure of the atmosphere.

TABLE OF THE PRESSURE, TEMPERATURE, VOLUME AND MECHANICAL EFFECT OF STEAM.

Total pressure in pounds per square inch.	Corresponding temperature.	Volume of steam compressed with volume of water.	Mechanical effect of a cubic inch of water evaporated in pounds raised one foot high.
1	102.9	20868	1739
2	126.1	10874	1812
3	141.0	7437	1859
4	152.3	4617	1895
5	161.4	5685	1924
15	212.8	1669	2086
20	228.5	1281	2135
25	241.0	1044	2175
30	251.6	883	2209
35	260.9	767	2238
40	269.1	669	2264
45	276.4	610	2287
50	283.2	554	2308
55	289.3	508	2327
60	295.6	470	2347
65	301.3	437	2365
70	305.4	418	2397
75	311.2	383	2411
80	315.8	362	2425
85	320.1	342	2438
90	332.	325	2464
100	....	295	....

A CHAPTER ON COMBUSTION.

(From "Steam Making or Boiler Practise," by the late Prof. C. A. Smith, C.E., M.E.)

"THE process of combustion is well known to be due to the act of uniting carbon and hydrogen with oxygen; other substances, such as sulphur and phosphorous, also develop heat when uniting with oxygen, but for our practical purposes carbon and hydrogen only need to be considered.

In fact, hydrogen is a very important element in fuel, although forming but a very small part by weight of ordinary coal, the fuel most in use as a combustible.

The first question which arises is, how much air must be supplied to our fuel in order to produce complete combustion, the air being required for the oxygen therein contained.

The quantity of air required varies with the composition of the fuel, but if we say that for each pound of fuel we must supply twelve pounds of air, we shall be sufficiently near the truth. The volume of air will, of course, depend upon its temperature.

Now, the quantity of heat which can be developed by the combustion of one pound of pure carbon, is sufficient to boil fifteen pounds of water from and at a temperature of 212° Fahrenheit if none of the heat was lost; but there are many reasons why we do not reach this result in practice, and they are as follows:

FIRST.—Variations in the quality of the coal as to its chemical constitution, affecting thereby its calorific power.

SECOND.—Impurities found with and mixed in the coal, affecting the actual quantity of pure coal in any given amount.

THIRD.—Imperfect or incomplete combustion of the fuel.

FOURTH.—Losses of heat from the furnace, the fire, and the metal of the boiler.

FIFTH.—The heat carried off in the stack, more or less utilized in the creation of draft.

1. *Variations in the quality of fuel.*—From the results of chemical analysis, the evaporative power of various kinds of fuel, expressed in pound of water per pound of fuel evaporated

from and at 212° F., which we will call E., have average values which are given in the following table :

KIND OF FUEL.	E.
Pure carbon completely burned to CO_2	15
Pure carbon incompletely burned CO	4.5
CO completely burned to CO_2	3.9
Charcoal from wood, dry	14
Charcoal from peat, dry	12
Coke, good, dry	14
Coke, average, dry	13.2
Coke, poor, dry	12.3
Coal, anthracite	15.3
Coal, dry, bituminous, best	15.9
Coal, bituminous	14
Coal, caking, bituminous, best	16
Coal, Illinois (from four mines near St. Louis)	12
Lignite	12.1
Peat, dry	10
Peat, with one-fourth water	7.5
Wood, dry	7.25
Wood, with one-fifth water	5.8
Wood, best, dry, pitch-pine	10
Mineral oils, about	22.6

Impurities in the coal being earthy matter, forms ashes in fires of low temperature, and slag or cinders in fires of high temperature ; water is also present which has to be evaporated, forming steam, and even decomposing into hydrogen and oxygen, thereby absorbing heat which passes off from the furnace ; in the latter case a re-combination may take place, whereby the heat of decomposition is given up, but that used in changing water into steam is lost by being carried off up the stack.

Imperfect Combustion.—Some coal is usually lost with the ashes by falling through the grate bars, especially with such kinds of coal as split in the fire. In some cases this is prevented by wetting the small coal, thus holding it together till when on the fire it swells and cakes by the heat ; it is, however, doubtful if this remedy is an economical one.

Taking all things together, we find in practice that the best coals are the English and Pittsburg soft coals; next in value the anthracites, which are only inferior by reason of their greater proportion of refuse, and the results are nearly the same for the best soft coals and anthracites. The Illinois coal near St. Louis is 80 per cent. in theory, but has rarely been found in practice to exceed 67 per cent. of the best coals.

Wood has about half the evaporative power of coal, and the usual comparison is to rate one cord, 128 cubic feet, equal to one ton of coal. The wood is supposed to be dry hard-wood or pitch-pine, and weighs about two tons. This is the practice of the master mechanics in this country in rating fuel in locomotives.

Indian corn has sometimes been burned and found when dry to be about equal to the same weight of wood. Corn-cobs have been found to be equal to one-third by weight of Illinois coal, or say one-fourth of good coal, or one-half of good wood by weight.

Incomplete combustion produces a very great loss, and this is best explained by a quotation from "Rankine's Steam Engine," page 270:

"The burning of carbon is always complete at first, that is "to say, one pound of carbon combines with two and two-"thirds pounds of oxygen, and makes three and two-thirds "pounds of carbonic acid, and although the carbon is solid "immediately before the combustion, it passes during the com-"bustion into the gaseous state, and the carbonic acid is gaseous, "this terminates the process when the layer of carbon is not "so thick can get direct access to all the solid carbon. The "quantity of heat produced is 14,500 thermel units as already "stated. But in other cases part of the solid carbon is not "supplied directly with oxygen, but is first heated and then "dissolved into the gaseous state by the hot carbonic acid gas "from the other parts of the furnace. The third and two-"thirds pounds of carbonic acid from one pound of carbon are "capable of dissolving an additional pound of carbon, making "four and two-thirds pounds of carbonic oxide gas, and the "volume of this gas is double that of the carbonic acid gas "which produces it.

"In this case the heat produced, instead of being that due "the complete combustion of one pound of carbon, equals "heat units, 14,500, falls to the amount, due to the imperfect "combustion of two pounds of carbon, or 2×4400 equals heat "units 8.800, showing a loss of heat to the amount of 5.700 "heat units, which disappears in volatizing the second pound "of carbon. Should the process stop there as it does in fur-"naces ill supplied with air, the waste of fuel is very great. "But when the four and two-thirds pounds of carbonic oxide gas "containing two pounds of carbon, is mixed with a sufficient "supply of fresh air, it burns with a blue flame combining "with an additional two and two-thirds pounds of oxygen, "making seven and one-third pounds of carbonic acid gas, and "giving additional heat of double the amount due to the com- "bustion of one and one-third pounds of carbonic oxide. That "is to say, 10,100×2 equals heat units, 20,200. To which "add the heat produced by the imperfect combustion of two "pounds of carbon 8,800.

There is obtained the heat due to the complete combustion of two pounds of carbon 2×14,500 heat equals units 29,000.

With coal that has little flame, a thin fire, with exactly the right draft, has been found to give the best results, producing exactly the effects in the first part of the quotation.

It may be doubted if such a bad state of affairs is often found in a boiler furnace of the present day as indicated in the middle of the quotation, though a tendency to an insufficient supply of air may exist in internally fired boilers, such as locomotives, if there is a very thick fire and no air admitted about the grate ; and, although not approaching remotely the case where no carbonic acid is produced, some of the carbonic oxide may pass off unburned, in such cases the admission of air about the fuel will be found beneficial.

In all soft coals there are found compounds of carbon and hydrogen known as hydro-carbons, which must also pass into the gaseous condition before being burned. "If these hydro-carbons, such as pitch, tar, naphtha, etc., are mixed on first issuing from the coal with a large quantity of air, these inflammable gases are completely burned with a transparent blue flame, producing carbonic acid and steam, but if raised to a red heat before being mixed with air enough, then disengage carbon in fine powder and the higher the temperature the more carbon they disengage. If this disengaged carbon is cooled below the temperature of ignition before "coming in contact with oxygen it constitutes while floating in gas smoke," and when deposited on solid bodies is soot.

But if this disengaged "carbon is maintained at the temperature of ignition, and supplied with oxygen sufficient for its combustion, it burns while floating in the inflammable gas with a red, yellow or white flame. The flame from fuel is the larger the more slowly its combustion is effected," and with the colors of flame given above as the combustion of smoke is less or more complete. An example of this is found in the use of common illuminating gas when burned with a "Bunsen" or a common burner. The chilling of the gaseous hydro-carbons, which are driven off from the solid pieces of coal by the heat developed, may take place in two ways—either by coming into contact with a cold body, as the iron of the boiler, or by finding too much cold air in the furnace. To fully sustain the latter statement, only a little consideration need be given to some of the fundamental principles of heat. It is well known that, if a certain amount of heat communicated to a body of certain weight and given material raises its temperature a definite number of degrees thereby, the same amount of heat communicated to twice the weight of the same material will only raise its temperature one-half the number of degrees that it was in the first case.

To apply this to combustion : One pound of carbon burned with twelve pounds of air gives thirteen pounds of gas at a temperature of 4580°F. [above] that of the external air ; but it is found that this rarely, if ever happens, and that to supply oxygen in plenty to the hot carbon surrounded by gas from 50 to 100 per cent. more air is used, and the result is from nineteen pounds of gas at a temperature of 3215°F. to twenty-five pounds of gas at a temperature of 2440°F. [above] the external air ; but if forty-eight pounds of air per pound of coal were admitted, the resulting temperature of the forty-nine pounds of gas would be about 1250°F. [above] the external air. With anthracite coal and coke, such a lowering of temperature is not accompanied by serious loss, but with bituminous and semi-bituminous coal, such a reduction of the temperature of the fire is always productive of great waste.

To examine this more closely, suppose a coal with one-half free carbon and one-half hydro-carbon set on fire by the heat. If such a coal were burned with twelve pounds of air per pound of coal, the temperature of the gas before the hydro-carbon ignited would be 2440°F., above the air, and the hydro-carbon would burn if supplied with oxygen enough and complete the combustion. Now if we burn this coal with twenty-four pounds of air per pound of coal, we have only about 1300°F., as temperature of the smoky product, and it is a question whether the gas would ignite; while with more air than this a great proportion of the gaseous fuel is lost and other evils are incurred.

We find, then, one marked point of difference between the anthracite and soft coal as fuel. While the former burns completely with a thin fire admitting an excess of air through it, and the free quantity of heat is developed, though the resulting temperature is not very high, the soft coal, on the contrary, absolutely requires for a perfect combustion a high temperature and plenty of room before coming in contact with the iron of the boiler, and any deviation from these conditions produces smoke and great loss of heating power; and that while with hard coal too great a draft only wastes a small quantity of heat in the stack, with soft coal too great a draft may be as bad, or even worse in its effects, than too little.

With soft coal the required high temperature over the fire may be produced by intercepting the radiant heat of the fire by a fire-brick arch or dome, which radiates back again to the fire, heating the products of combustion from both sides.

This was first introduced by Mr. C. Wye Williams, many years ago, and has been frequently revived in different forms since. In some devices air is introduced at the bridge, or at the edges of the arch or dome.

The great trouble with such arrangements has always been the lack of durability of the brick, used in the arch or dome. In fact, the more refractory the material the hotter the fire, and the destruction of the arch becomes only a question of, what is comparatively, a short time. One of the satisfactory ways of obtaining a high temperature is by using so thick a bed of coal that the passage of too great a quantity of air is prevented by its friction upon the fuel, the thickness of fire being regulated by the size of the coal used, and kept so that it will not clinker too much. This effectually raises the temperature of the fire; it may also be done by the use of a damper, but not in so satisfactory a manner, although there is found to be in many cases a marked improvement by decrease in the draft. The general opinion in this country is decidedly in favor of thin fires, and the experiments of Professor Johnson at Washington favor this practice; but the experiments at Wigan, England, gave generally "the thicker the fire the better the result." Experiments with a pyrometer are needed in each case, but we may safely say that great improvement can be made in our practice in this respect, and that the only secret in smoke prevention is to have a hot fire with room and time to let all the gas burn before coming to less than a red heat, and to fire in small quantities over a part of the grate at one time only.

Losses of heat by radiation and conduction from the furnace and ash-pit of externally fired boilers are to be provided against by making the walls, if of brick, in two thicknesses, with an air space between them; by keeping the ash-pit doors partially closed, and covering all radiating surfaces of metal with some good non-conducting material, such as thick felt faced on the inside with one-quarter inch of asbestos.

The amount of heat which may be lost by radiation from uncovered iron surfaces, exposed to air on one side and steam on the other, may be estimated as *two and six-tenths* heat units per square foot per hour per degree F. of difference of temperature between the steam and the air. If the air in the room be still, this amount may not be reached, but if exposed to violent winds it may be exceeded.

The heat passing up the chimney is not wholly lost, but is useful in producing a draft; and it can be shown that in a chimney where the draft is produced by the excess of weight of the outside air over that of the hot gas in the chimney, that the greatest quantity of gas by weight will pass up the chimney when the temperature of the gas in the chimney is about 625° F. hotter than the external air. With higher temperature the velocity of flow will be greater, and the quantity of gas by weight will be less, owing to its greatest volume. Looked at as a means of burning coal for making steam, the most coal that can be burned to advantage in a given time in a boiler furnace is when the temperature in the stack is near, but does not exceed, that of melting lead. A higher temperature than this means that the heat has not been properly taken out of the gas, and points to an increase in the boiler surface as a means of improving the performance of the boiler and increasing the yield of steam, as well as the economy of its production; a less temperature than the above is always desirable if the required quantity of steam can be maintained. In case twenty-four pounds of air per pound of fuel is used, the temperature of stack giving maximum quantity of coal burned, requires a little more than one-fourth of the heat generated to maintain the draft and the other three-quarters should pass into the water of the boiler. If we could get along with only twelve pounds of air per pound of fuel, only one-eighth of the heat generated would be required to maintain maximum draft. With forty-eight pounds of air per pound of fuel, one-half of the heat generated would be used in maintaining maximum draft. Here again the importance of hot fires is plainly indicated, and there is yet another reason for them: With a hot fire more of the heat generated passes into the water near the fire, leaving the products of combustion at a lower temperature to traverse the remainder of the surface and to leave the boiler at a lower temperature. More of the heat generated is therefore utilized than when the fire is not so hot.

A simple relation between the height of the stack in feet above the grate, its area in square feet, and the number of pounds of coal per minute burned, is the following equation, where:

h = height in feet of the stack.
A = Area in square feet of stack.
F = Number of pounds of coal burned per minute.

$$h = \left\{ \frac{5\,F}{A} \right\}^2 \qquad A = \left\{ \frac{5\,F}{\sqrt{h}} \right\} \qquad F = \left\{ \frac{A\sqrt{h}}{5} \right\}$$

It is understood, however, that A is the "least flue area" in the passage of the hot gas.

The effects of changing the flue area, or as it is called the "calorimeter," and the proportions of heating surface and calorimeter to grate area are seen in my table of boiler trials.

Gas has been employed as a fuel in boiler furnaces to a limited extent for some years past, principally in Europe. As little data on this subject is extant, we do not consider it advisible to embody it in this work.

SPECIMEN PAPER ON COAL AND COMBUSTION.

BITUMINOUS, ANALYSIS:

$75\frac{1}{4}$ per cent. of		....	Carbon.
$4\frac{1}{4}$	"	"	Hydrogen.
16	"	"	Nitrogen.
$4\frac{1}{2}$	"	"	Ashes.
100 parts of coal.			

The coal burns, throwing out light and heavy carburetted hydrogen, carbonic acid gas, carbonic oxide, etc., each of which as it produces heat will combine only with its proper proportion of oxygen; therefore, if more be supplied by introducing too much fresh air, it does injury, not only by cooling the internal surface of the flues, but remembering that a high temperature is necessary to produce combustion, by preventing loss of gas, it has been proved that hydrogen furnishes weight for weight, four times as much heat as carbon, therefore $4\frac{1}{4}$ parts of hydrogen in coal will produce $4\frac{1}{4} \times 4 = 17$ parts of heat to the carbon's $75\frac{1}{4}$.

The 80 pounds (say) of carbon will require 2527 cubic feet of oxygen for its combustion which will be supplied by 12635 cubic feet of atmospheric air. The hydrogen will require 473 cubic feet of oxygen which will be found in 2365 cubic feet of air, making a total of $12635 + 2365 = 15000$ cubic feet of air for combustion of 100 pounds of coal.

The foregoing calculation is based on, say in round numbers, we may say, 80 per cent. of coal is carbon and five per cent. (=20 per cent. of heat) is hydrogen in 100 parts.

Out of 100 pounds of coal eighty parts are carbon and five parts are hydrogen,

Then,

Hydrogen $5 \times 4 =$ .... 20 parts of heat.
80 " carbon.
———
100

80 parts of carbon requires 2527 cubic feet of oxygen.
5 hydrogen.

12635

473 cubic feet oxygen for hydrogen.
5 hydrogen.

2365

Then,

2365
12635

15000 cubic feet of air required for the combustion of one hundred parts of coal.

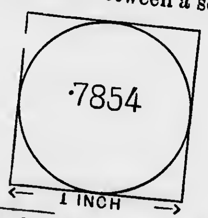
MISCELLANEOUS CALCULATIONS FOR ENGINEERS.

"THE derivation of 'calculation,' alludes to that rudimental period of the Science of Numbers, when pebbles or stones (calculi) were used, as now, among savages, they often are to facilitate the practice of counting," etc.—*Trench on Words.*

The name of decimals with their equivalent fraction:

NAME.	DECIMAL.	FRACTION.
One-tenth,	.1	$\frac{1}{10}$
One-hundredth,	.01	$\frac{1}{100}$
One-thousandth,	.001	$\frac{1}{1000}$
Ten-thousandth,	.0001	$\frac{1}{10000}$
One-hundred-thousandth,	.00001	$\frac{1}{100000}$
One-millionth,	.000001	$\frac{1}{1000000}$
One-eighth=one hundred and twenty-five thousandths	(.125)	$\frac{1}{8}$
One-quarter=twenty-five hundredths..............	(.25)	$\frac{1}{4}$
One-third=thirty-three hundredths..............	(.33)	$\frac{1}{3}$
One-half=five-tenths	(.5)	$\frac{1}{2}$
Seven-sixteenths=five thousand three hundred and seventy-five ten thousandths...........	(.5375)	$\frac{7}{16}$
Nine-sixteenths=five thousand six hundred and twenty-five ten thousandths............	(.5625)	$\frac{9}{16}$
Five-eighths=six hundred and twenty-five thousandths	(.625)	$\frac{5}{8}$
Three-quarters=seventy-five hundredths..........	(.75)	$\frac{3}{4}$

Difference between a square inch and a circular inch:



1	square inch.
.7854	circular inch.
.2146	difference.

NOTE.—Cyphers to the right of a decimal are of no value, as .10 is one-tenth, the same as .1; but cyphers to the left of a decimal reduces its value ten times, as .1, one-tenth; .01, one-hundredth.

The difference between a circular (or decimal) inch and a square inch is .2146; and the difference is a square with one for its diameter and a circle with one for its diameter ; so then

4 : 3.1416 : : 1=7854:—

The constant number or multiplier for the horse-power of an engine, instead of using .7854 to multiply with and 3300 to divide with, is found by dividing .7854 by 330000, which will equal .0000238 constant multiplier for horse-power of an engine, etc.

Example:

```
33000).78540000(.0000238
       66000
       ------
       125400
        99000
       ------
        264000
        264000
        ------
```

Then we find that in the calculations where .7854 is used to multiply with and 33000 to divide with, the same result will be attained by multiplying by the constant multiplier .0000238.

AMERICAN RULE FOR THE PRESSURE ALLOWABLE ON BOILERS OF GIVEN DIMENSIONS.

RULE.—Multiply one-sixth ($\frac{1}{6}$) of the lowest tensile strength found stamped on any plate in the cylindrical shell, by the thickness expressed in inches, or parts of an inch (decimally), and divide by half the diameter (expressed in inches), the sum will be the number of pounds allowable for single riveted boilers, and for double riveted boilers add 20 % (twenty per cent.)

Taking 50400 pounds as the lowest tensile strength of any plate and diameter of boiler 42 inches, of $\frac{1}{4}$ inch plate:

```
        50000 lbs. tensile strength.
            1
        -----
      6)50000
        -----
         8400 one-sixth of plate.
          .25 thickness.
        -----
        42000
diam.   16800
2)42    -----
--
   21)2100.00(100 lbs. pressure per square inch for single
      21             riveted boiler and 120 lbs. for double
      --             riveted boiler.
       0
       0
       -
       0
       0
       -
```

Taking 60000 lbs. tensile strength and 42″ diameter $\frac{1}{4}$ of an inch plate:

```
        6)60000
          -----
          10000
2)42        .25
--        -----
   21)2500.00(119 lbs. for single riveted and 142.8
      21              lbs. double riveted boiler.
      --
      40
      21
      ---
      190
      189
      ---
        1
```

BRITISH BOARD OF TRADE RULE.

To find the pressure that may be carried on a circular boiler of 12 feet diameter, $\frac{7}{8}$ of an inch thickness of plate and 51520 51520 lbs. tensile strength:

```
    51520
        7
  -------
 8)360640
  -------
    45080
        2
  -------
144)90160(626          626
    864                .70
    ---              ------
     376         100)438 20
     288             ------
     ---           6)438.2
      880            ------
      864              73 lbs. working pressure per
      ---                      square inch.
       16
```

Taking tensile strength at 60000 lbs. per square inch, and a $\frac{1}{4}$ of an inch plate, 42 inches diameter boiler; find pressure that may be carried according to the above method.

```
     4)60000
      ------
       15000
           2
      ------
  42)30000(714            714
     294                  .70
     ---               -------
     ..60             6)499.80
       42              -------
      ---               83.3 lbs. working pres-
       180                        sure per square
       168                        inch.
       ---
        12
```

Taking 50400 lbs. per square inch tensile strength $\frac{7}{8}''$ plate, 12 feet diameter:

```
    50400
        7
  -------
 8)352800
  -------
    44100
        2
   ------
144)88200(612
    864                612
    ---                .70
    180            -------
    144           6)428.40
    ---             ------
    360              71.4 lbs. per square inch
    288                        working pressure.
    ---
     72
```

USEFUL QUANTITIES.

The following are sufficiently correct for all practical purposes; but they are not scientifically accurate:

One gallon equals $\frac{1}{6}$ of a cubic foot, or $6\frac{1}{2}$ gallons equals one cubic foot. One gallon of fresh water weighs ten (10) pounds. Thirty-five (35) cubic feet of sea water weighs one (1) ton. One cubic foot of fresh water weighs $62\frac{1}{2}$ lbs., equals 1,000 ounces. One cubic foot of salt (sea) water weighs sixty-four pounds. One gallon sea water weighs $10\frac{1}{4}$ lbs. 1,728 cubic inches make one cubic foot; tweuty-seven cubic feet make one cubic yard.

THE RATIO OF EXPANSION OF STEAM, ETC.

A short rule for the ratio of gains of expansion is, add 37 to steam pressure of gauge, and divide by 22, equals the proper ratio of the expansion.

Example.—$90+37 = 127 \div 22 = 5.77$ best ratio of expansion.

Tensile strength: If a bar, 1″ square, of iron is torn asunder by a strain of 4,500, what force will be required to break a bar 3″ square?

$$1'' : 3^2 :: 4{,}500$$
$$1 : 9 :: 4{,}500$$

```
      4,500
          9
     ------
  1)40,500
     ------
     40,500 lbs.
```

Calculate the weight of an iron ball six inch by six inch diameter.

```
   6″                    .1377 constant number
   6″                     216
  ---                    -----
  36                     8262
   6                    1377
  ---                  2754
  216 cube of ball.    -------
                       29.7432 lbs. weight.
```

Now as this is only a little over one quarter of a pound too heavy, it may be used with a good deal of certainty when scales are not handy, or the ball not easy to remove, etc.; for a 6″x6″ iron ball weighs by scale 29.484 lbs. and by calculation 29.7432 lbs., showing a little over a quarter of a pound in error.

To what height must a safety-valve, 8″ diameter, be lifted to allow a free escape of steam equal to area of valve?

Rule:

$$\frac{d^2 \times .7854}{d \times 3.1416} = \frac{d}{4}$$

$$8 \times 8 = \frac{64 \times .7854}{8 \times 3.1416} = \frac{50.2656}{25.1328} = 2'' \text{ or } \frac{8}{4} = \frac{{}^48}{2''} \text{ height.}$$

To what breadth of opening must a five-inch safety-valve rise to allow the escape of 9,200 lbs. of steam per hour at 72 lbs. pressure per square inch? Then

Gauge pressure, 72
Atmos, " 15
Total pressure, 87 lbs. per sq. inch.

72 : 60 :: 87
87
420
480
72)5020
74.57
60 per min.
4474.20 lbs. per hour.

4474.2 : 9200 :: 1 sq. inch = 2.05 sq. inch escape.
2.0561
3.1416 = 1.308 of an inch lift, or $\frac{1}{8}$ of an inch.

Then, 4474.2 : 9200 :: 1 = 2 square inches = $\frac{1}{8}''$ breadth of opening.

RULE IN FULL FOR THE METHOD OF CALCULATING THE WEIGHT ON THE END OF A SAFETY VALVE-LEVER, ETC.

1st. Multiply the square of the diameter of the valve by .7854; the product will be the area of valve.

2nd. Multiply the area of valve by the pressure per square inch; the product is the pressure on valve, or upward pressure.

3rd. From this product or upward pressure (2nd) subtract the sum of the weight of the lever and valve or pressure downwards; the remainder is the effective pressure on the valve.

4th. Multiply the remainder (3rd) by distance from fulcrum to valve and divide by distance from fulcrum to weight; the quotient is the weight required.

Example.—Required the weight to be placed on the end of a safety-valve lever to be equal to 25 lbs. per square inch on the valve, the distance from the fulcrum to valve 4", from valve to weight 25; valve $3\frac{7}{8}''$ diameter. Weight lever, 24 lbs., 8 oz.; valve, 3 lbs. 8 oz.

$3.875^2 \times .7854 = 11.7932$ area of valve $\times$ 25 lbs. pressure = 294.83 lbs. pressure on valve—27.875 lbs. weights of lever and valve $= 266.955 \times 4 = 1067.820 \div 29\ (25+41) = 36\frac{3}{4}$ lbs. weight required.

How to calculate the weight on a direct weighted safety-valve when its diameter is $3\frac{1}{4}''$; pressure 70 lbs. per square inch:

$3.25 \times 3.25 \times .7854 \times 70 = 580.7$ lbs. weight. Being very nearly $580\frac{3}{4}$ lbs. direct weight required.

To find the weight to be placed on a double beat-valve to be equal to a given number of pounds, having diameter of valves given:

Rule.—Multiply the sum of the diameters by their differences multiplied by .7854 plus pressure equals answer.

Required the weight to be placed on double beat-valve to equal 32 lbs. per square inch; the diameter of valves being 8″x6″. Then,

$$8-6 = 2 \text{ and } 8+6 = 14 \times 2 = 28$$

Then, $28 \times .7854 = 21.9912 \times 32 = 70.3$ lbs. required.

MOLWORTH'S RULE FOR THE AREA OF SAFETY VALVE.

The grate surface in feet multiplied by 8, what is the area of a safety valve for a boiler with 23.6 square feet of area of grate surface?

Then, $23.6 \times 8 = 18.88$ square inches, area of safety-valve by Molworth's Rule.

The following table of proportion of safety-valves gives areas, diameters, openings and dimensions:

Area of valve...........	5	10	15	20	25	30
Diameter of openings....	2.525	3.37	4.371	5.447	5.642	6.781
Diameter of valve.......	2.76	3.77	4.58	5.28	5.86	6.375
Length of lever.........	25	30	35	40	45	47.5
Distance of fulcrum.....	2.5	3	3.5	4	4.5	4.75

PRESSURE FOR A DIRECT LOADED SAFETY-VALVE.

Sum.—Safety-valve $4\frac{1}{2}''$ diameter, loaded, with six 70 lbs. weights and nine 60 lbs.; the valve weighs 9 lbs. and spindles 16 lbs.

$4.5^2 \times .7854 = 15.904350$ area of valve.

```
70 lbs          60
 6               9
---             --
420             540
                420
                ---
                960 lbs.
                  9
                 16
                ---
                985 lbs.
```

Then 15.9)985.00(61.9 lbs. pressure.

```
954
---
 310
 159
 ---
 1510
 1431
 ----
   79
```

A safety-valve is loaded to 65 lbs. by direct weight of 990 lbs., how much is required to be taken off to reduce pressure to 50 lbs.?

```
65
50
--
15
```

$65 : 15 :: 990 = 228\frac{1}{2}$ lbs.

What is the stroke of an engine, the diameter of which is 30 inches, pressure 23.2 lbs., revolutions 58, H. P. 125?

$$\frac{30^2 \times .7854}{3.3000} \times \frac{23.2}{125} \times 58 \times 2 = \frac{1902301}{41250.00} \text{ (invert)} = 2'\ 2''$$

To compute the diameter of a stay bolt. Pressure 70 lbs. per square inch; distance apart of bolts 8 inches. What should the diameter be?

$\frac{70}{5530} = \sqrt{.01265} = .1125 \times 8 = 9 = \frac{9}{10}$ of inch,

or $\frac{70}{600} = \sqrt{.1060} = \frac{14}{16}$ of an inch.

Proof, $\frac{5530}{70} = \sqrt{79} = .889 \times 9 = 8$ inches apart.

$\frac{600}{70} = \sqrt{.85} = 9.26 = 8$ inches apart.

To find the boiler pressure. Diameter of cylinders being 23″ and 45″; length stroke 33″; diameter crank shaft 8″.

Rule:

$$\frac{Sd^3 - 15SD^2}{.SH^2} \quad S = 4936 \text{ cr. and } 5660$$

D dia. L. P. cylinder, H dia. of H. P. cylinder.

$$5636 \times 8^2 - \underline{15 \times 33 \times 45^3} = \frac{2527232 - 1002375}{17457}$$

= 87.3 lbs.; the answer.

Required the area of a circle the diameter of which is 1, (D).

Rule.—Multiply radius by circumference and halve the product.

Note.—The circumference of a circle being its diameter in the proportion to the radius as is 3.1416 (a number that we shall designate by H the Greek letter Pi) to ½ and hence the truth of the above rule.

Here R. $= \frac{D}{2}$, or ½; the area is $\frac{1}{2} \times \frac{H}{2}$, or $\frac{3.1416}{4} = .7854$.

Then we find that .7854 is the area of a circle whose diameter is one inch (1″).

.7854 is called a decimal of an inch, or the decimal of a circular inch, a decimal inch, or a circular inch. It is used in all calculations containing area, etc.; as, 4 : 3.1416 :: 1 = .7854.

When you square a number and multiply it by .7854, you are getting its area.

If you double a number you increase its area four times. Any number to be multiplied by the decimal .25 if divided by 4 will give same result, cutting off two figures for decimal places.

How to calculate the diameter of a shaft, submitted simultaneously to torsion and flexure: from Prof. Mark's "Steam Engine."

First.—Calculate the diameters for torsion and flexure singly.

Second.—If the diameter due to torsion be the greater, divide it by the sixth root of the expression, unity minus the quotient of the cube of the diameter due to the torsion, and the result will be the required diameter.

Thirdly.—If the diameter due to flexure be the greater, divide it by the cube root of the expression. Unity minus the quotient of the sixth power of the diameter due to torsion divided by the sixth power of the diameter due to flexure, and the result will be the required diameter.

Claudel gives the following rule: "Calculate the diameter of the shaft to resist each strain separately. Take the greatest of the two value; if the largest diameter is given by the effort of torsion, augment it by $\frac{1}{8}$ to $\frac{1}{10}$": but this rule gives too small value.

The algebraic formula would stand thus:

$$\left\{1-\left\{\frac{d^4f}{d^4}\right\}^3\right\}^{-\frac{1}{6}}=\left\{1+\tfrac{1}{6}\frac{d^4f^3}{d^{4\,3}}+\tfrac{7}{72}\left\{\frac{d^4f}{d^4}\right\}^6+\text{etc.}\right\}$$

Torsion gives greatest value, then

$$d^4=d^4t\left\{1+\tfrac{1}{6}\frac{d^3_4f}{d^3_4t}+\tfrac{7}{72}\left\{\frac{d^4f}{d^4t}\right\}^6+\text{etc.}\right.$$

When flexure gives the greater diameter:

$$\text{Then } d^4=d^4f\left\{1+\tfrac{1}{3}\frac{d^4t^6}{d^6_4f}+\tfrac{2}{9}\left\{\frac{d^4t}{d^4f}\right\}^{14}+\text{etc.}\right.$$

To calculate the pressure that is on the valve per square inch of the safety valve, the valve being 5 inches diameter, weight of ball at end of lever $13\frac{3}{4}$ lbs., length of lever 30 inches, 3 inch fulcrum, 4 lbs. weight of valve, etc., lever, etc.:

```
                      13.75 lbs. weight
                      30 lever
                  ---------
              Ful. 4)412.50
                  ---------
                     137.50
                       4
                    -------
32 × .7854 = 7.0686)141.5000(20 lbs. steam pressure per sq.
                    141 372              inch on valve.
                    -------
                       1280
```

The weight being 112.7625 lbs., lever 16 inches long and 6 inches fulcrum, effective weight of parts 92 lbs. (valve, spindle, lever and spindle, etc.), and the area of valve 19.6350 what pressure, per sq. inch, of steam would be on valve.

Weight 112.7625 lbs. or little over 112¾ lbs.
16 lever

6765750
1127625

Fulcrum 6)1804.2000

300.7000
92 lbs. effective weight.

Area valve 19.6350)392.7000(20 lbs. pressure steam per sq. inch on valve.
392700

0
0

Formula $\frac{W \times L + DW}{FA} = P.$,

Rule.—Weight multiplied by lever add dead weight and divide by fulcrum and area equals pressure.

What quantity of water will a feed pump deliver per hour, size pump 3″ diameter, 14″ stroke, 25 strokes per minute, $\frac{5}{8}$ full each stroke:

$3^2 = 9 \times .7854 = 7.0686 \times 14 = 98,9604 \times \frac{5}{8}$ ($\times 5 \div 8$) $\times 25 \times 60 \div 1728 = 53.689$ cubic feet.

What pressure would a smoke box $\frac{3}{8}$″ thick, stayed every 7″, stand as a working pressure:

$7 \times 7 - 6 = 43 \quad \frac{3}{8} \times \frac{6}{16}$

$6 + 1 = 7 \times 7 = 49 \times 100 = \frac{4900}{43} = 114$ lbs. (nearly)

What is the pressure allowable on a flue 37″ in diameter, length 6′ 9″, plate $\frac{3}{8}$″ thick.

6′.9″+1 = 7′.9″ = 7.75 × 37 = 286.75

90000 × 3 ÷ 8 = 33750 × 3 ÷ 8 = 12656.20

∴ 12656.20 ÷ 236.75 = 44 lbs. per sq. inch.

Calculate the area of safety valve and diameter from the grate surface, the area of grate surface being 25 square feet, the area will be just half = 12 5 sq. inches.

```
∴ .7854)12.5000(15.91
        7854
        -----
        46460          15.91(3.98 diameter of valve.
        39270           9
        -----          ---
         71800       69)691
         70686          621
         -----          ---
          12140     788).70 00
           7854          63 04
           ----          -----
           3286            696
                           ---
```

25 square feet *grate surface* = $12\frac{1}{2}$ sq. inches *area* = 3.98 *inch diameter of valve.*

RANKINE'S RULE FOR CAPACITY OF FEED PUMP (ABRIDGED).

To provide for leakage of water and steam priming, blowing off and loss by the safety valves, the feed pump of a land engine should be of such capacity as to discharge from double to two and a half times the net feed of water required by the engine according to

$$\frac{.08285}{2.875} = .0288 \text{ lbs.} = .00046 \text{ cubic foot.}$$

Temperature being 257°, pressure 33.71 lbs. = 4854 lbs. per square foot, ratio of cut-off 2.875, and .08285 weight of a cubic foot in pounds, then the net feed water per cubic foot swept through by the piston would be .0288 lbs. = .00046 cubic foot mean effective pressure 18.25 lbs. square inch or 2629 lbs. square foot ÷ 33000 =12.55 × 60 = 753 cubic feet per hour for each indicated horse-power.

Then the net feed per indicated horse-power per hour:— .0288 × 753 = 21.7 lbs. = 0.347 cubic foot.

In marine engines a further addition to the capacity of the feed pump must be made to provide for the brine that is blown off or pumped out. Ordinary sea water contains $\frac{1}{32}$ of its weight of salt. Brine in boilers should never be allowed to rise much above double the strength of the ordinary sea water;

and for this the brine discharge should be equal to half the volume of the net feed water. The discharge capacity of the feed pumps of a marine engine, three or four times the volume of the net feed water.

SOME EXERCISE IN DECIMALS FOR PRACTICE AND EXAMPLE.

Sometimes in reducing vulgar to decimal fractions the quotient never comes, as $\frac{1}{6} = .16666\dot{6}$—called a repeating decimal is written $.1\dot{6}$ and the 6 is called a repeater. Sometime instead of one figure repeating itself, as above, you will find two or more as $\frac{1}{7} = .14285714285\dot{7}$. This is called a circulating decimal and is written $.14285\dot{7}$.

Bring $\frac{1}{3}$ to a decimal.

$$\frac{1}{3} = 3)1.0000000$$
$$.3333333 \text{ or } .3\dot{3}.$$

Bring $\frac{1}{4}$ to a decimal.

$$\frac{1}{4} = 4)100$$
$$.25$$

Bring $\frac{15}{16}$ to a decimal $= .9375$

$$4)15.00\ 00$$
$$4)5.7500$$
$$.9375 \text{ answer.}$$

How many eighths are there in .114

$.114 \times 8 = .912 =$ near $\frac{1}{8}$ (one eighth).

How many sixteenths are there in .198—answer 3.

$.198 \times 16 = 3.16\ 8$ or a little over $\frac{3}{16}$.

Multiply .00072 by $.0502 = .050036144$.

Multiply $.0002 \times .00101 = .000000202$.

To reduce 8 inches to a decimal of a foot.

RULE.—Add a cypher and divide by 12.

$$12)8.00$$
$$.666+ \text{or } .\dot{6}$$

Reduce 7 feet 7 inches to decimal of foot equals 7.583 feet.

To find the Mean Pressure throughout the stroke, steam working expansively.

Sum: Steam is admitted into the cylinder at 65 lbs. per square inch, above the atmosphere and is cut off at $\frac{2}{5}$ the stroke required, the mean pressure on piston throughout the stroke, supposing the vacuum to be perfect.

Cut off $\frac{2}{5} = \frac{4}{10}$ and also .4 decimally expressed.

Then,

lbs.			
40	0	.05	Value of ordinates above the cut off are each = .1 except first = .05.
80	1	.1	
80	2	.1	
80	3	.1	
80	4	.1	
64	5 = .4÷5 =	.08	Value of ordinates below cut off found by divide cut off decimally expressed by number of degree of cut off.
53.33	6 = .4÷6 =	.066666·	
45.71440	7 = .4÷7 =	.057143	
40	8 = .4÷8 =	.05	
35.55	9 = .4÷9 =	.044444	
16	10 = .4÷10÷2=	.02	
10)613.59440		.768253	

61.35944 lbs. mean pressure

15 vac. + 65 lbs. steam = 80 lbs. total pressure per sq. inch.

61.460240 lbs. mean pressure per sq. inch throughout stroke.

NOMINAL HORSE-POWER.

What is the nominal horse-power of an engine when the diameter of cylinder is 54 inches, stroke 35, revolutions per minute 30.

$$\frac{D2V}{6000}\quad \begin{cases} D2 = \text{square of diameter of cylinder.} \\ V = \text{velocity, or travel of piston per minute in feet.} \end{cases}$$

$$\frac{54^2 \times 180}{6000} = 87.48 \text{ N. H. P.}$$

This formula was used by the British Admiralty for paddle-wheel steamers.

How many bolts $1\frac{1}{2}$ inch diameter are required for a cylinder cover 60 inches diameter, the boiler pressure 50 lbs. per square inch, the strain (bolts measuring from thread) not to exceed 2000 pounds.

$$\frac{60^2 \times .7854 \times 50}{15^2 \times 7854 \times 2000} \text{ 40 Bolts.}$$

Tensile strength: If a bar of iron one inch square is torn asunder by a strain of 23 tons, what force will be required to break a bar $3\frac{3}{4}''$:

$$3.75 \times 3.75 \times 51520(-2240 \times 23) = 7245021 \text{ lbs.}$$

How many cubic feet of water will be extracted in an hour by a brine pump 3 ins. diameter, and 10 inches stroke, making 18 revs. per minute, the pump being $\frac{2}{3}$ full each stroke.

$3^2 \times .7854 \times 10 \times 2 \div 3 \times 60 \times 18 \div 1728 = 29.45$ cubic feet of water extracted by this size pump in an hour.

How many gallons of water are required for a steam boiler per horse-power, per hour, say at 60 lbs. pressure.

At the Centennial Exhibition, Philadelphia, at tests, trials, etc., thirty (30) lbs. of steam per horse-power per hour was taken as the standard. This is a little less than half a gallon, but it depends much on the character and condition of the engine through which the steam is worked. The quantity of water may vary from one third ($\frac{1}{3}$) of a gallon to two-thirds ($\frac{2}{3}$) of a gallon and even one gallon in a very bad engine.

STAYS.

A boiler 10′ 6″ long 9′ 7″ wide, how many stays $1\frac{1}{2}''$ diameter will be required, each stay to bear 6000 lbs. per square inch, steam pressure 24.34 lbs.

$$\begin{array}{r} 10' \ 6'' = 126 \\ 9' \ 7'' = 115 \\ \hline 14490 \\ 24.34 \\ \hline 6000)352686.60 \\ \hline \text{Area stay } 1.769)58.78 \end{array}$$

```
                                  33.26)14490 sq. in area
                                        ------
                                        435.6(20.87 ins. from centre
1.767 area of stay.                     4                   to centre.
33.26 number of stays.                 ----
20.87 ins. centre to centre.      408)3560
6000 lbs. pressure allowed            3264
  on stay.                            ----
24.34 steam pressure per         4167)29600
  square inch.                         29169
                                       -----
```

RULES FOR THE NOMINAL HORSE-POWER OF ENGINES.

Rules in general commercial use:—

Low pressure engine, $\frac{\text{Diameter cyldr. in inches}^2 \text{ velocity piston.}}{6000}$

or, $\frac{D^2 \times V}{6000} = \text{N.H.P.}$ Say $\frac{54^2 \times 180}{6000} = 87.48 \text{ N.H.P.}$

As the speed of the piston increases with length of stroke in proportion, nearly, as the cube root of the length of stroke, then the above sum, and any low pressure engine's nominal horse-power can be calculated correctly and quickly by the following method:

$$\frac{D^2 \times \text{cube root of stroke}}{47} = \text{N.H.P.}$$

High pressure engine: $\frac{\text{diam. cyldr.}^2 \times \text{cube root stroke}}{15.6} = \text{N.H.P.}$

Compound Engine:—

Rule.—Square the diameter of low pressure and add to it the square of the high pressure cylinder, divide by 30, or by 32 and it will give the nominal horse-power.

Watt's Rules for engines:—

$$\frac{\text{Diameter of cylinder}^2 \times .7854 \times 7 \times \text{actual travel piston.}}{33000}$$

which may be abbreviated into

$$\frac{d^2 \times .7854 \times 7 \times t}{33000} \text{ or } \frac{d^2}{27.28} = \text{nominal horse-power.}$$

HORSE-POWER.

The following remarks on horse-power, abridged from an excellent little work by Robt. Grimshaw, M.E., will be interesting and somewhat novel.

"In order to calculate the horse-power of an engine we must have, or know the following elements:

Mean effective pressure, length of stroke, area of and piston rotation, (or, number of revolutions per minute). The deduction from friction, leakage, cylinder condensation, etc., varies. The larger and better the engine and the better its condition, the less the allowance. As a rough figure, say from 20 per cent. down to 12½ per cent.; or $\frac{1}{5}$ to $\frac{1}{8}$.

"As the horse-power of an engine depends upon so many elements, this question cannot be answered in a general way." (How large an engine will give, say, 18 horse-power.)

"The following list shows a number of engines and conditions that will yield in theory, 18 horse:

Cylinder diameter in inches.	Stroke inches.	Revolutions per minute.	Clearance proportion.	Cut off.	Actual Expansion rate.	Limited pressure above atmos.	Average total pressure.	Initial pressure above vacuum.	Back pressure above atmos.	Mean effective pressure.	Horse-power.
6	18	200	.05	.625	1.56	40.4	60.22	98	7.7	52.5	18
6	18	200	.02	.25	3.78	84 18	60.22	65	7 7	52.5	18
9	9	190	.05	.625	1.56	29 03	40.76	43	7.7	32.7	18
9	9	190	.02	.25	3.78	51.72	40.76	66	7.7	32.7	18
10	10	180	.05	.625	1 56	20.8	32.91	35	7.7	25.2	18
10	10	180	.02	.25	3 78	39 34	32 91	54	7 7	25 2	18
9	9	190	.05	.25	1.56	39 34	50 4	82	17.7	35	18
7	12	97	.02	.25	3 78	80.	87	94.7	7.7	79	17.98

MEAN EFFECTIVE PRESSURE.

Mean effective pressure is generally expressed in pounds per square inch, length of stroke in feet, piston area in square inches and rotation speed in times per minute.

The "factor of horse-power" is a conventional term not much used in the East, and means the products of mean effective pressure and area, and speed of the steam piston by 33000. Thus when the area of piston is expressed in square inches, and its speed in feet per minute, the so-called "factor of horse-power" multiplied by the mean effective pressure in pounds per square inch gives the horse-power of the engine.

An English horse-power, such as we reckon by, is the power required to raise 33000 lbs. one foot high in a minute, or 550 lbs. one foot high in a second, or 1,980,000 lbs. one foot high in an hour.

One cubic inch of water evaporating at 14.7 lbs. per square inch and making 1.641.5 cubic inches of steam, at 212° F., would in a vertical cylinder of one square inch bore raise 14.7 lbs. 1641 5—1 = 1640.5 inches = 136.7 feet, doing 14.7 × 1367 = 2009 foot pounds of work; supposing one pound of coal to give out in its complete and perfect combustion, to carbonic acid, 14000 heat units, this is the equivalent of 14000 × 772 = 11008000 foot pounds, and this

Equal $\frac{11008000}{33000 \times 60} = 5.56$ horse-power if exerted in 1 hour.

If exerted in one minute it would be $\frac{11008000}{33000} = 333.6$ H. P.

HOW TO CALCULATE THE EXTERNAL PRESSURE ON FLUES, ETC.

The Steamboat inspection Act and Rules, 1882, give the following data to work from:

"The external working pressure to be allowed on circular furnaces and flues subjected to such pressure, when the longitudinal joints are welded, or made within a butt strap, shall be determined by the following formula:—

"The product of 90000 multiplied by the square of the thickness of the plate in inches—divided by the length of flue or furnace in feet plus 1, multiplied by the diameter in inches, will be the allowable working pressure per square inch in lbs.—provided it does not exceed that found by the following formula:

"The product of 8000 multiplied by the thickness of the plate in inches, divided by the diameter of the furnace or flue in inches, will be the allowable working pressure per square inch in pounds."

"The length of the furnace to be used in the first formula, being the distance between rings, if the furnace is made with rings; and that one of the two formulæ which gives the lowest pressure being the one by which the Inspector shall be guided: page 8, section 17, sub-section 7.

Formula $\frac{90000 \times t^2}{D \times L+1} = P = \frac{90000 \times .25}{39.6} = 96.15$ lbs. pressure.

Rule.—Multiply the decimal thickness of plate by itself and this product by 90000 (or 60000, etc., as case may be, *vide* s. 13 Inspection Act of 1882, page 28, section 27), and divide the amount by the product of the diameter of flue or furnace in inches multipled by the length in feet with one added to it.

Example:—Thickness of plate being ½ inch and the furnace 3 feet 3 inches diameter, 5 feet long, what pressure is allowable, according to "S. B. I. Act '82."

```
                         .5 = ½
                         .5
                         ———
 3′ 3″                   .25 = squared
12                         90000 constant
———                      ————
39″×5+1 = 234)22500.00(96.15 lbs. pressure per square inch.
                         2106
                         ———
39 = (3′ 3″)              1440
 6 = (5+1)                1404
———                       ———
234 Divisor                360            2nd method.
                           234             8000
                           ———               .5 = ½″
                           1260          ————
                           1170         39)4000.0(102.5 lbs.
                           ———            39
                             90           ——
                                          100
                                           78
                                          ——
                                          220
                                           95
                                           —
                                           25
```

or, by fractions in following manner:

```
                         ½ 2)90000
                             ————
                       ½ = 2)45000
                             ————
3′ 3″ = 39″×6 = 234)2250.0(96 lbs. pressure per square inch.
                    2106
                    ———
                     1440
                     1404
                     ———
                       36
```

Second Example:—What is the pressure allowable on a flue, etc., 37 inches in diameter, 6 feet 9 inches long, of $\frac{3}{8}$ inch plate, made in best manner, etc.:

```
                     .375 = 3/8
                     .375                        2nd method.
                     ----                           8000
6'9"                 1875                           .375
1                   2625                            ----
---                1125                           40000
7'9" = 7.75 ft.    ----                          56000
   37             .140625                       24000
                       90000                    -----
Divisor 286.75 ) 12656.250000(44.0124        37)3000000(81 lbs.
                 114700                         296        pres.
                 ------                         ---
                  11825                          40
                  11470                          37
                  -----                          --
                   35500                          3
                   28675
                   -----
                    68250
                    57350
                    -----
                   109000
                   114600
```

CANADIAN RULE FOR NOMINAL HORSE-POWER.

How to calculate the nominal horse-power as applied to grading of engineers, in Act of 1882.

Rule for ordinary condensing engines: square the diameter, multiply by number of cylinders and divide by 30, equals the nominal horse-power.

Calculate the N. H. P. of a one cylinder 25 inch condensing engine.

Formula $\frac{D^2 \times N}{30}$ = nominal horse-power

Then, diameter cylinder $25'' \times 25 \times 1 \div 30 = 20.8$ nominal horse-power.

Rule for compound condensing engines: the square of the low pressure cylinder in inches added to the square of the high pressure cylinder in inches or by the following:

$$\text{Formula } \frac{(D^2 \times N) + d^2 \times n}{30} = \text{nominal horse-power.}$$

D = Diameter of low pressure cylinder in inches.
d = Diameter of high pressure cylinder in inches.
N = Number of low pressure cylinders.
n = Number of high pressure cylinders.

What nominal horse-power would a compound engine be, low pressure cylinder 30 inches, high pressure cylinder 17 inches:

$$30 \times 30 = 900$$
$$17 \times 17 = 289$$

```
30)1189(39.6 nominal horse-power.
   90
   ---
   289
   270
   ---
    190
    180
    ---
     10
```

NOMINAL HORSE-POWER.

The following extract from Turnbull's "Short Treatise on the Compound Steam Engine" explains the nominal horse-power of steam engine in a sensible and comprehensible manner.

"It has been explained in the first part of this work that the nominal horse-power of an engine is ascertained by assuming the mean pressure on the piston to be equal to seven pounds on the square inch, and the speed of piston equal to

220 feet per minute. But as both the working pressure and speed of piston have been greatly increased since the above rule was first adopted, it fails to carry any adequate idea of the actual capacity of the engine. Still, in all negotiations connected with the purchase of a steam engine, it is as a rule, the nominal horse-power alone that is referred to, although it is understood that with a pressure, say of about 60 pounds, and a piston speed of about 400 feet per minute, fully six times the nominal horse-power is got from a condensing engine.

"As the term 'nominal horse-power' is only used when speaking of the steam engine as a marketable commodity, a particular size of cylinder may be called a certain nominal power by one maker, and different nominal power by another, and unfair competition often takes place by two manufacturers, offering for sale say an eighty horse-power condensing engine one of whom means to give a cylinder 50 inches in diameter, whilst the other calls a 40 inch cylinder the same nominal power. The rules now generally adopted in this country to determine the nominal power of the different kinds of steam engines are as follows:—

"Rule to find the nominal horse-power of a high pressure non-condensing steam engine: square the diameter of cylinder in inches, and divide by twelve, that is to say, a non-condensing engine with a cylinder equal to 30 inches diameter, is called a 75 horse-power engine nominal, although it is capable of giving out at least three times the power when a pressure of say 60 pounds is employed and piston speed equal to 400 feet per minute.

"Rule to find the nominal horse-power of a single cylinder condensing engine: square the diameter of cylinder in inches, and divide by 24, that is to say, that a condensing steam engine with an equal to 30 inch cylinder is called a $37\frac{1}{2}$ horse-power engine nominal, but is capable of working to at least six times its nominal power with 60 pounds pressure and speed of piston equal to 400 feet per minute.

"The rule now generally adopted by marine engineers for the nominal power of a compound engine is: add the square of the diameter of each cylinder in inches together, and divide the sum by 30, that is with a compound engine whose condensing cylinder is 30 inches diameter, and high pressure cylinder 17 inches diameter, is called a 40 horse-power compound engine nominal, and is also capable of working to at least six times that power with 60 pounds pressure and speed of piston equal to 400 feet per minute."

The following circular issued by the Board of Steamboat Inspection, of Canada, in regard to rules for calculating nominal horse-power as therein abridged explains itself:

"Inspectors of steamboats are to substitute the Imperial Board of Trade rules for estimating the nominal horse-power of marine engines in place of Bourne's rules heretofore in use, viz.:

For ordinary condensing engines,

D = diameter of cylinder in inches.
N = number of cylinders.

Then, $\frac{D^2 \times N}{30}$ = nominal horse-power.

For compound condensing engines,

D = diameter of low pressure cylinder in inches.
d = diameter of high pressure cylinder in inches.
N = number of low pressure cylinders.
n = number of high pressure cylinders.

Then, $\frac{(D^2 \times N) + d^2 \times n}{30}$ = nominal horse-power.

HOW TO CALCULATE THE HORSE-POWER FROM GRATE SURFACE.

There are three boilers with three furnaces each, the diameter of each fire grate is 3 feet 3 inches: how many tons of coal will be consumed per day? how many horse-power will be indicated?

This question depends upon the fact that 1 ton of coal is considered to be burnt for every foot's width of fire-bars and that $2\frac{1}{2}$ pounds of coal per hour equals one horse-power.

$3'3'' \times 3 \times 3 = 29'.3'' = 29\frac{1}{4}$ tons per day.
$29\frac{1}{4} \times 2240 \div 24 = 2730$ lbs. per hour.
$\therefore$ I. H. P. $= 2730 \div 2.5 = 1092$ I. H. P.,

```
         3.25 = 3 ft. 3 ins.
            3
         ----
         9.75
            3
         ----
        29.25 tons per day.
         2240
        -----
        97000
       5800
      5850
      -------
24 { 3)65320.00 lbs. per day.
     ----------
   { 8)21780.00
     ----------
  2.5)2730.00(1092 indicated horse-power.
      25
      ---
       230
       225
       ---
         50
         50
         --
```

Answer: { $29\frac{1}{4}$ tons of coal per day.
2730 lbs. per hour.
65320 lbs. per day.
1092 indicated horse-power. }

PRESSURE ALLOWED ON COMBUSTION BOX.

How to calculate the pressure allowable per square inch on combustion box or chamber.

When the top of combustion chamber, boxes, or other parts of a boiler, are supported by solid rectangular girders, the following formula, which is used by the Board of Trade, will be useful for finding the working pressure to be allowed on the girders, assuming that they are not subjected on the, or, to a greater temperature than ordinary heat of steam and are further sustained by hanging stays as provided by section 12 of the Act and in case of "combustion," that the ends are fitted to the edges of the tube plate and the back plate of the combustion box.

$$\frac{C \times d^2 \times T}{W - P \times D \times L} = \text{working pressure.}$$

W = width of combustion box in inches.

P = pitch of supporting bolts in inches.

D = distance between the girders from centre to centre in inches.

L = length of girders in feet.

d = depth of girders in inches.

T = thickness of girders in inches.

C = 500, when girder is fitted with 1 supporting bolt.

C = 750, when girder is fitted with 2 to 3 supporting bolts.

C = 850, when girder is fitted with 4 supporting bolts.

The working pressure for the supporting bolts and for the plate between them shall be determined by the rule for ordinary stays.

Depth girder in inches, 5; thickness of girder 2 inches, width of combustion chamber 36 inches, distance between girders 8 inches, length of girder 3 feet, pitch 8 inches:—

Then $C = \dfrac{750 \times 5^2 \times 2}{36 - 8 \times 8 \times 3}$ 55.8 lbs. pressure.

```
 36 = W
  8 = P                  750 = C
 ---                      25 = square depth of girder.
 28                     ----
 24 = D×L               3750
 ---                   1500
112                    -----
 36                    18750
 ---                       2
672 =                  -----
                  672)37500(55.8 lbs. pressure allowable
                      3360       per sq. inch in combus-
                      -----      tion box, or chamber.
                       3900
                       3360
                       -----
                        5400
                        5376
                        ----
                          24
```

By Reed's formula:

```
           36   12000
           36      25
          ---   -----
          216   60000
         108   24000
         ----  ------
         1396  300000
            8       2
       ------  ------
       10368)600000(57.87 lbs. pressure.
             51840
             -----
              81600
              72576
              -----
               90240
               82944
               -----
                72960
                72576
                -----
                  384
```

What quantity of water will a feed pump deliver per hour; size of pump 3 inches diameter and 14 inches stroke, 25 strokes per minute, $\frac{5}{8}$ full each stroke:

3×3=9×.7854=7.0686 area of pump.
7.0686 area×14=98.9604 contents.
98.9604 contents of pump in cubic inches × $\frac{5}{8}$ (which is 98.9604×5÷8)×25×60÷1728=53.68 cubic feet per hour.

What diameter should the safety-valve be for a boiler containing two furnaces three feet diameter and 5½ feet long:

5½ ft. = 5.5 length of grate surface.
3 feet diameter grate surface.

16.5 sq. ft. grate surface in one furnace.
2

2)33.0 sq. ft. of grate surface in boiler.

16.5 area in sq. inches for safety-valve.

Area of safety-valve:

.7854)16.5000000(21.0084
15708

7920
7854

66000
62832

31680
31416

264

√21.0084(4.58 ins. diam. of valve.
16

85)500
425

908)7584
7264

320

Abbreviated:—5½×3×2÷2÷.7854=√21.0084=4.58; or, 4½ inches diameter of safety-valve for a boiler with above area of valve or 33 square feet of grate surface.

HOW TO CALCULATE THE THROW OF THE ECCENTRIC,

The size of steam port and lap of valve being given. What is the throw of the eccentric, the steam port being one inch and lap half inch:

$1+\frac{1}{2}\times 2=3$ inches throw of the eccentric, etc., which is double port and lap.

Reed's "Handbook" formula for rectangular cross bars for combustion chamber crowns:—

B = boiler pressure.
D = distance apart of bars.
L = length of bars.
d = depth of bars.
t = thickness of bars.

Then, $$\frac{12000d^2\times t}{DL^2}=B$$

Or, $$\frac{12000\times 8^2\times 1\frac{7}{8}}{16\times 30\times 30}=100 \text{ lbs.}$$

WHAT IS POWER.

Power, in mechanics, is the product of pressure and motion; or the result of a certain pressure acting at a certain velocity, etc.

A machine or steam engine in motion is power.

The effect produced by running machinery.

STEEL FOR SAFETY-VALVE SPRING.

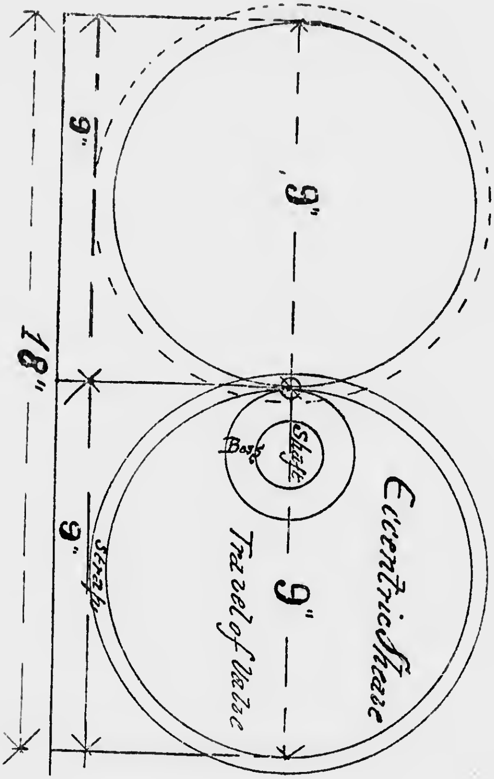
How to calculate the steel of which the spring is made in spring safety-valves, if found from the following formula:—

$$\frac{3\sqrt{S\times D}}{C}=d$$

S = the load on the spring in pounds.
D = the diameter of the spring in inches.
d = the diameter or side of square of wire in inches.
C = 8000 for round steel.
C = 10000 for square steel.

The diameter of a spring loaded safety-valve is to be five inches, pressure sixty pounds, mean diameter of the spiral spring five inches; what must be the diameter of the steel?

$$\frac{(.7854\times 5^2\times 60\times 5)^{\frac{1}{3}}}{8000}=.9 \text{ of an inch.}$$



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USEFUL INFORMATION ON HYDRAULICS.

A gallon of water (U. S. standard) weighs $8\frac{1}{3}$ pounds and contains 231 cubic inches.

A gallon of water (British standard) weighs 10 pounds and contains 277 cubic inches.

A cubic foot of water weighs $62\frac{1}{2}$ pounds, contains 1728 cubic inches, or $7\frac{1}{2}$ gallons; $6\frac{1}{4}$ gallon in a cubic foot.

Each nominal horse-power of boilers require one cubic foot horse-power.

In calculating horse-power of steam boilers consider for

Tubular boilers	15 sq. ft. of heating surface equal to 1 h. p.
Flue boilers	12 sq. ft. of heating surface equal to 1 h. p.
Cylinder boilers	10 sq. ft. of heating surface equal to 1 h. p.

Salt water weighs more than fresh according to density.

BOILER-MAKING BY A BOILER-MAKER.

To get the thickness of plate for a given pressure the formula is, $\frac{P\,D}{C\,J} = t$; which means to multiply the pressure by the diameter and divide by the sum of the constant multiplied by the per cent.

```
             78.125=pressure.          200=constant.
                 48=diam.                6=per cent.
             -------                   ---
 200         625000                   1200
   6         312500
----         ------
1200        )3750.000(.3125=thickness of plate.
             3600
             ----
              1500
              1200
              ----
              3000
              2400
              ----
               6000
               6000
```

The formula to get the per cent. of rivet to solid plate, is $\frac{n\ a}{p\ t} = Z$, which means to multiply the number by the area and divide by the sum of thickness of plate, multiplied by pitch of rivets. Example :

.3125=thickness.
2=pitch.
.6250

.306796=area of ⅝ rivet.
1=number of rivets.

.6250).306796(49=Z, per cent compared with solid plate.
25000
56796
56250
546

These rules give a low per cent. of joint and rivet, but there is no doubt, if they were followed up, that they would be safe ; but I am sure there are but few who think anything about rules of this description. By United States law we could get 97 lbs. pressure on same size boiler with same tensile strength (44,800). The rule is to multiply the thickness of plate in inches by one-sixth of the tensile strength and divide the product by the radius of boiler. Where there are so many rules, and all different, a man is very apt to throw them all away and work according to his own judgment, but some judgments are very poor. Witness the bracing in some boilers made by "judgment." You will find them (the braces) spaced from ten to fifteen inches apart and often more. Let us see how much stress braces will have to bear at ten inches between centers : The square of ten is 100, and 100 multiplied by the pressure will give the strain on the brace. The boiler will be intended, perhaps, to carry 100 lbs. Then, 100×100 gives 10,000 ; ten thousand pounds that the brace has to sustain. If 150 lbs. is on the boiler, there would be 15,000 lbs. Possibly the brace will be of ¾ or ⅞ round iron. The rule is not to have more than 6000 lbs. to the square inch of area of brace. Now the area of ¾ round iron is only .4417, or not quite half a square inch for the ¾ round brace, and but little over half a square inch for a ⅞. If this is pointed out to some men, they will "pooh-pooh" at it, and assert that the crow-feet, or angle, or tee-irons take up some of the space ! What if it does? The strain goes through the brace first and last, and if it does not hold, the crowfeet won't keep the head in. If boiler-makers would adopt some one safe rule, and work by it, their boilers would be better. Supposing we take 6000 as the standard (Wilson gives 4000), and, as most all stationary and portable boilers are tested to 150 lbs. cold water pressure, use that pressure to work by. Now, if 1″ round iron is used for braces, we can put them 6″ apart, and be safe. The square of 6 is 36, and that multiplied by 150 gives 5400 lbs. per square inch, and as the square of one inch round is .7854 we would have the brace about right—that is, with iron of good quality.

There are some who will not believe that there is any more on the braces than what the gauge shows, or that there is any more in the whole boiler. There are other times when you will see braces put close together about the centre, or just above the tubes, and a space of 9″ to 12″ between braces and flange of head. That is, I consider, robbing Peter to pay Paul. Many think if the centre of pressure is secured, the boiler is all right. I got taken in on that plan myself, once, but only once. It was at a time when we were rushed with work, and thought I would try it, for one boiler, to see how it would work, but before I got the full test on I wished I had not done it. When there was only 120 lbs. on, I could see the space above the braces dishing out. I did not wait to measure how much it came out, but put five more braces on each head, where, if I had had common sense, I would have saved four braces, or two on each head; but I was made to understand that there was as much pressure near the flange as there was in the middle, to the square inch. The flange certainly stiffens around the heel and a little away from it, but unless it is properly done it does not strengthen, but quite the reverse. Some flange-turners may be seen knocking the flange in and out about a half dozen times before it suits them, and they only stop because it is too cold. Even when the flange is cold they take a heavy sledge and drive the flange out or in. If the head breaks under this usage it is the fault of the iron or steel, and those heads will be sent back to the mill and others had in their place. The mill has to replace stuff that won't stand working! The greatest care should be taken with all flanging, as it is generally the weakest that has to stand the most strains, and as domes, drums, and boiler-heads, are never proportionate to the strength of shell, they should be well braced.

HOW TO FIND THE CUBIC FEET OF STEAM USED IN CYLINDER.

Example.—How many cubic feet of steam will be used per hour by a pair of engines making forty-seven revolutions per minute, the diameter of the cylinder being forty-two inches, the stroke forty-two inches, the cut-off being ½ of the stroke from the beginning.

```
    42" diam.
    42
    ——
    84
   168
   ————
  1764 sq. of diam.
  .7854
  ————
  7056
  8820
 14112
12348
——————
1385.4456 area.
```

```
    1385.4456 area.
           42 revs.
    ———————
     96981192
    55417824
    ————————
    65115.9432
           60 per m.
    ——————————
   3906956.5920
           84 twice stroke.
   ——————————
   156278263680
  312556527360
  ——————————
½)328184353.7280
  ——————————
  164092176.864
              2
  ——————————
  328184353.728 cubic ins.
```

$$\frac{328184353.728}{1728} = \text{cubic feet.}$$

FIND THE WEIGHT OF BOILER PLATE.

Example.—A boiler plate 6 feet 9 inches long, 4 feet 6 inches wide and $\frac{3}{8}$ of an inch thick, find the weight:

Length 6 feet 9 inches × width 4 feet 6 inches × thickness.

```
Length 81 inches.              3.6 { 6)1640.25
Width  54   "                      { 6)273 375
       ---
       324                     28  { 4)455.625
      405                          { 7)113—3
      ----                               4)16—1
      4374                                 4. 0 7½
         3                              cwt. qr. lbs.
     -----
    8)13122
     -------
     1640.25
```

Since the plate in question contains 1640.25 cubic inches, and 3.6 inches of wrought iron weighs 1 lb., on dividing the former quantity by the latter, the weight in pounds of the plate is found as above; since one square foot of wrought iron weighs 5 lbs. for every $\frac{1}{8}$ of an inch of thickness; then $\frac{3}{8}$ inch of plate will weigh 15 lbs. per square foot; hence, by multiplying the square feet of plate by 15 we obtain the weight in pounds.

```
   9 inches = 9½ = .75
                  ----
 ∴ 6 ft. 9 ins. = 6.75 ft.        28 { 4)455.625
                  4.5                { 7)113—3
                 ----                  4)16.—1
                 3375                   4. 0. 7½ lbs.
                2700
                -----
                30375 sq. feet.
                   15
               ------
               151875
               30375
               ------
Weight of plate = 455625 lbs.
```

RULE FOR AMOUNT OF HEATING SURFACE IN BOILER.

Example.—Required the heating surface in the tubes and tube-plates of a boiler, the tubes being $2\frac{1}{2}$ inches in diameter, 8 feet 3 inches in length, and 462 in number and the plates 19 feet 8 inches long, by 8 feet 7 inches wide.

Heating surface of tubes = 2.5 inches × 3.1416 × 99 inches × 462=

```
         3.1416
            2.5 inches diameter.
        -------
         157080
         62832
        -------
        7.85400 circumference.
             99 length of tubes (8 feet 8 inches.)
       --------
        7068600
       7068600
      ---------
      777.54600 heating surface of one tube.
            462  number of tubes.
     ----------
        1555092
       4665276
      3110184
    -----------
    359226.252 heating surface in tubes.
```

To find the area of plates:

```
Length 19 ft. 8 ins. =        236 ins.      2.5 × 2.5=6.25
 Width 8 ft. 7 ins. =         103 "      6.25 × .7854=4.908750
                              -----
                               708          4.908750 × 462=
                              2360
                              -----
Area of plates,               24308      = 2267.82425 area of
Area of tube's mouth,       2267.8225              tube mouths.
                           ------------
Heating surface 1 plate,   22040.1575 ins.
                                    2
                           ------------
Heating surface 2 plate,   44080.3150
```

Heating surface in tubes = 359226.252 sq. ins.
Heating surface in plates = 44080.315

403306.567 square ins.

of heating surface or $\frac{403306.567}{144} = 2800.74$ square feet.

How to calculate the pressure to be allowed on plate forming flat surfaces.

The working pressure allowable on flat surfaces shall not exceed 6000 pounds to each effective square inch of sectional area of the stay supporting it. The pressure to be allowed on plates forming flat surfaces shall be that found by the following formula:

$$\frac{C \times (T+1)2}{S-6} = \text{working pressure in lbs. per sq. inch.}$$

Which means, equal to constant $\times$ (thickness of plate in sixteenth of an inch add 1) $\times 2 \div$ surface supported in square inches $-6=$ working pressure.

C equal to constant equal to 100; but when plates are exposed to the impact of heat or flame, and the steam only is in contact on the plates on the opposite side, then C is to be reduced to 50:

$$\frac{\overset{C}{50} \times (\overset{T\frac{8}{16}}{8+1})^2}{15^2-6}$$

$8+1=9\times9=$ 81
50

$15^2-6=219$)4050(18.12 lbs.
219
1860
1832
280
219
610
438
172

81
100
219)8100(37 lbs.
657
1530
1533

SAFETY-VALVE SUMS.

To find the length of safety-valve lever, area of valve being 19.6350; pressure per square inch 25 pounds; weight of valve, spindle, lever, etc., 90 pounds; 4 inch length of the fulcrum; weight of ball 76.34 pounds.

```
              19.6350 area of valve=5" diameter.
                   25 lbs. pressure per sq. inch.
              -------
               981750
              392700
              -------
             490 8750
              90        effective weight of parts.
             --------
             400 8750
                    4 fulcrum.
             --------
Ball 76.34)16035000(21 inches length of lever.
           15268
           -----
             7670
             7634
             ----
               36
```

To find the length of the safety-valve fulcrum for a lever 21 inches long, 25 pounds pressure per square inch, 5 inches diameter of valve, 76.34 pounds weight of ball required for end of lever.

Rule $\dfrac{\text{area} \times \text{pressure} - \text{d Wt}}{\text{weight of ball} \times \text{L of Lever.}} = \text{length of fulcrum.}$

```
5×5×.7854=19.6350
                25
           -------
   76.34    981750
      21   392700
   -----   --------
    7634   490.8750
  15268     90
  -------  --------
 1603.14   400.8750)16031400(4 inches is nearly cor-
                    16035000   rect length in this
                    --------   case for the length
                               of fulcrum.
```

ENGINES.

Taking into consideration the proportionate load, large engines are most economical.

The best possible results can be got out of a non-condensing engine by keeping the full pressure clear up to the point of cut-off and expanding down nearly to the atmospheric pressure (supposing free exhaust and admission and minimum clearance, friction, leakage and condensation).

The water consumption of an engine in pounds per hour, may be calculated: 859375 by the volume of steam at the termal pressure and by the mean effective pressure.

The "economy" or "duty" of a steam engine ought to be expressed in pounds of water consumed per hour per horse-power and not in pounds of fuel per hour per horse-power.

High-pressure is the most economical for initial cylinder pressure.

The advantage of dry steam is on account of it lessening the danger to cylinder head by water being in the steam, etc.

CONDENSERS.

Explain the difference between a jet and a surface condenser? A jet condenser is one in which exhaust steam is condensed by coming in contact with a spray of cold water from a pump; and a surface condenser is a condenser in which the exhaust steam is condensed by contact with tubes kept cold by circulation of water, and a good condenser should add twelve to fifteen pounds to the effective result of the pressure, and the advantage of using one of the surface type is, it allows the same feed water being used over many times, which is a great advantage when pure, good, soft water is scarce, and the objections are chiefly because it is apt to cause corrosion in the boiler when animal oils are used in the cylinder and steam chest, etc.

Twenty or twenty-five times the weight of water is necessary for the injection of a jet, to maintain a good vacuum, with a medium temperature.

The greatest gain in using the condenser is largest when the piston area is greatest. The gain depends upon the effective pressure mean and back, before adding condenser upon degree of vacuum obtained and amount of power expended in operating the condenser.

It takes from one to two gallons of water per minute to each horse-power to operate a condenser.

CONNECTING ROD.

Calculate the thickness of the connecting rod:—

RULE.—.0179 cylinder diameter times the square root of boiler pressure, or 12.753 times the square root of the quotient of indicated horse-power by product of stroke in inches, and strokes per minute.

Sum:—Engine 20 inches diameter of cylinder, 48 stroke, 80 pounds pressure:

First method: $20 \times 48 : .0179 \times 20 \times \sqrt{80} = 3.22$ or $3\frac{1}{4}$.

```
 .0179
   .20
 -----
 .3580
     9 the square root of pressure.
 -----
3.2220 = 3¼ thickness connecting rod.
```

Second method:

$$20^2 \times 4 \times 50 \times 80 \times .0000238 = \frac{\sqrt{152}}{48 \times 50} \times 12.753 = 3\tfrac{1}{2}''.$$

Sum second:—Engine 18 inches diameter of cylinder, 48 inches stroke, 75 strokes per minute, calculate thickness required for connecting-rod by above rules:

First method:

```
 .0179 constant multiplied.
    18 inches diameter of cylinder.
 -----
  1432
  179
 -----
 .3222
     9 = √81
 -----
2.8998 thickness required by 1st method.
```

Second method:

```
  48 stroke in inches.
  75 strokes per minute.
 ---
 240
336
----
3600
```

```
3600)140.000(.0388888
     108 00
     ------
      32000          .03888888(.197 sq. root.
      28800           1
      -----           --
       32000       29)288
       28800          261
       -----          ---
        32000     387)2788
        28800          2789
        -----          ----
        32000
```

.197×12.753 = 2″.524341 thickness connecting rod.

Calculate the proper thickness of a cylinder.

RULE.—.00033 times the boiler pressure in pounds per square inch, plus .8 inches, or .8 plus $\frac{1}{100}$ the cylinder diameter.

Sum:—16 inches diameter of cylinder, 130 pounds boiler pressure:

```
First method:     .00033 constant number.
                     130
                  ------
                     990
                    33
                  ------
                  .04290
                      16
                  ------
                   25740
                   4290
                  ------
                  .68640
                   8
                  ------
                  1.48640 or 1½ inches thickness cylinder.
By second method:  100)16.00(.16
                        100   8
                        ---  --
                        600 .96  or nearly 1″ thickness
                        600            cylinder.
```

Cylinder heads, if flat, should have as thickness .003 times the bore, times the square root of the boiler pressure. This would give for 16-inch cylinder 130 pounds pressure, .5473 inches, which is thinner than the cylinder walls; 16-inch engine 81 pounds pressure equal to .432 inch, while the cylinder itself would be 1.2277 inches of which .8 is the allowance for re-boring, etc. The distance between cylinder head bolts should be close enough not to permit leakage between head and flange of cylinder, and the thickness should be in diameter half the width of the cylinder flange.

Calculate the distance apart of cylinder head bolts.

RULE.—Calculate the above as follows:—.0001571 times the square of the cylinder diameter, times the square of the cylinder diameter, times the boiler pressure, divide by area of one bolts.

Sum:—Cylinder 16 inches, 130 pounds pressure, ¾ of an inch bolts, calculate the number of bolts.

```
            16 inches diameter of cylinder.
            16
            ——
            96
           16
           ———
          256 square of cylinder.
     .0001571 constant number.
     ————————
          256
        1792
       1280
       256
      ———————
     .0402176
          130
     ————————
     12065280
     402176
     ———————
4.3282850)5.2263880(12 number of bolts.
          4 3282850
          —————————
           90000300
           86565600
           ————————
            3434700
```

Formula: $\frac{\text{sq. D clydr} \times .0001571 \times P}{\text{area of bolts.}} = \text{number bolts.}$

Or, taking the Canadian standard, 6000,

$$\frac{256 \times 130}{6000 \times .5625} = 9.8 \text{ or say 10 bolts.}$$

How to calculate the diameter of a stay.

RULE.—The square feet of flat surface in boiler multiplied by 144 to bring to square inches, divide this by number row stays plus 1, divide this product by number stays plus 1, and multiply by pressure and divide by 5000, or 6000 as allowed by law.

Sum:—A boiler with 186 square feet of flat bottom, a pressure of 30 pounds per square inch, 7 row of nine stays each, 5000 allowed by English law.

```
               186 square feet flat surface.
               144
               ---
               744          } 6.000 allowed by Canadian
              744           }    law, to each square inch
             186            }    of iron in stay.
             -----
(7+1) = 8)26784
             -----
(9+1) = 10)3348
             ----
             334.8
                 30 pounds pressure.
           -------  area.
5000)1004.40(2.0088÷.7854 = 2.56(1.6 diam. of stay.
     1000 0                    1
     -------                  ---
       44000               26)156
       40000                  156
       ------                 ---
        40000
        40000
        -----
```

Or, 1004.40÷6000 = 1.00073 area stay = 1.12 diam. stay.

Formula: $\dfrac{FS \times P}{\text{R. S. constant}}$ $\dfrac{\sqrt{\text{area}}}{.6854}$ = diameter of stay.

Formula Rule:

$$\frac{\text{Flat surface in sq. inches} \div \text{No. row No. stay} \times \text{pres.}}{5000} = \text{area stay.}$$

Area of stay÷.7854, the square root of this is diameter of stay.

How to calculate the heating surface for boiler from the tubes.

Rule—formula: $\dfrac{\text{Circum. tubes} \times h \times \text{No. tubes}}{144} = \text{H. S.}$

Tube=3″=9″.4248 circumference of one 3″ tube.
120″ length of tube=10 feet.

```
1130.9760
      45 tubes.
---------
56548900
45239040
---------
144)508940200(353.4307   or 353½ sq. feet heating surface.
    432
    ---
     769
     720
     ---
      494
      432
      ---
       620
       576
       ---
        442
        432
        ---
         1000
         1008
         ----
```

2″ diameter tube = 6.″2832 circumference tube.

```
      120″ = 10 feet length tube.
   ------
   1256640
   92834
   ------
   753.9840
         71 tubes.
   -------
   7539840
  52778880
  ---------
144)53532.8640(371 sq. feet heating surface.
  432
  ---
  1033
  1008
  ----
   272
   144
   ---
   28 8
```

THE CIRCLE.

The diameter of a circle equals the circumference multiplied by 0.31831.

The diameter of a circle equals the square root of the area multiplied by 1.12838.

The side of an inscribed equilateral triangle equals the diameter of the circle multiplied by 0.86.

The side of an inscribed square equals the diameter of a circle multiplied by 0.7071.

The side of an inscribed square equals the circumference of the circle multiplied by 0.225.

The circumference of a circle multiplied by 0.282 equals one side of a square of the same area.

The side of a square equals the diameter of a circle of the same area multiplied by 0.8862.

The area of a triangle equals the base multiplied by one-half its altitude.

The area of an ellipse equals the product of both diameters and .7854.

The solidity of a sphere equals its surface multiplied by one-sixth of its diameter.

The surface equals the product of the diameter and circumference.

The surface of a sphere equals the square of the diameter multiplied by 3.1416.

The surface equals the square of the circumference multiplied by 0.3183.

The solidity of a sphere equals the cube of the diameter multiplied by 0.5236.

The diameter of a sphere equals the square root of the surface multiplied by 0.56419.

SQUARE AND CUBE ROOT.

The first essential for the learner is to make himself familiar with the following properties of numbers:

1. A square number multiplied by a square number, the product will be a square number.
2. A square number divided by a square number, the quotient is a square.
3. A cube number multiplied by a cube, the product is a cube.
4. A cube number divided by a cube, the quotient will be a cube.
5. If the square root of a number is a composite number, the square itself may be divided into integer square factors; but if the root is a prime number, the square cannot be seperated into square factors without fractions.
6. If the unit figure of a square number is 5, we may multiply by the square number 4, and we shall have another square, whose unite period will be ciphers.
7. If the unit figure of a cube is 5, we may multiply by the cube number 8, and produce another cube, whose unit period will be ciphers.
8. If a supposed cube, whose unit figure is 5, be multiplied by 8, and the product does not give 3 ciphers on the right, the number is not a cube.

TO FIND THE SQUARE ROOT OF A NUMBER.

RULE 1. Seperate the given number into periods of two figures each, beginning at the unit's place.

2. Find the greatest number whose square is contained in the period on the left; this will be the first figure in the root. Subtract the square of this figure from the period on the left; to the remainder annex the next period to form a dividend.

3. Divide this dividend, omitting the figure on the right, by double the part of the root already found, and annex the quotient to that part, and also to the divisor; then multiply the divisor thus completed by the figure of the root last obtained, and subtract the product from the dividend.

4. If there are more periods to be brought down, continue the operation in the same manner as before.

NOTE 1. If a cipher occurs in the root, annex a cipher to the trial divisor, and another period to the dividend, and proceed as before.

2. If there is a remainder after the root of the last period is found, annex periods of ciphers, and continue the root to as many decimal places as required.

Example.—Find the square root of 1016064.

```
      1,01,60,64(1008
      1
      ---------
2008) 016064
       16064
       -----
       .....
```

NOTE.—The square root of a fraction may be found by extracting the square root of the numerator and denominator seperately.

CUBE ROOT, ETC.

Remarks on the method of extracting cube root:—

By observing the table we see the entire part of the cube root of any number below 1000, will be less than 10, and will contain but one figure. The entire part of the cube root of a number containing four, five and six figures, will contain two figures and so on with the larger numbers.

TABLE

Comparing the natural numbers with the unit figures of their squares and cubes. By the use of this many roots may be extracted by simple observation:

Numbers,	1	2	3	4	5	6	7	8	9	10
Squares,	1	4	9	16	25	36	49	64	81	100
Cubes,	1	8	27	64	125	216	343	512	729	1000

EXPERIMENTS ON PLATE WITH AND ACROSS FIBRE.

Ultimate strength when drawn in the direction of fibre is from 19.66 tons to 20.2 tons.

The ultimate strength when broken across the fibre is from 16.93 tons to 17 tons; one sample broke at 16.7 tons.

The ultimate extension was also twice as great when the plate was broken in the direction of the fibre.

The best scrap rivet, iron, broke on an average with 24 tons per square inch, mean ultimate extension, which was uniform $\frac{1}{8}$ of the length.

Mr. E. Clark observes that we may generally assume the ultimate tensile strength of wrought iron bars at 24, and of wrought iron plate at 20 tons per square inch, and within this latter limit, its extension may be taken at $\frac{8}{100000}$ of the length per ton square inch of section.

It is said, on good authority, that English boiler plates are of two classes—Yorkshire, and the manufacture of other districts, classed as Staffordshire. The ultimate strength of boiler plate averages as follows:

Best Yorkshire, per square inch,			25 tons.
Best Staffordshire,	"	"	20 tons.
American best,	"	"	31 tons.
American ordinary,	"	"	27 tons.

Some experiments by Mr. Brunel, on Staffordshire plates, averages 20.6 tons per square inch.

Woolwich dockyard experiments on Staffordshire plates average 20 tons per square inch.

TABLES.

MELTING POINT OF METALS.

Name.	Fahr.		Authority.
Platina,	4593°		
Antimony,	842 to 955		J. Lonthian Bell.
Bismuth,	487 to 507		J. Lonthian Bell.
Tin,	average 475		J. Lonthian Bell.
Lead,	average 622		J. Lonthian Bell.
Zinc,	722		J. Lonthian Bell.
Cast Iron,	2786	{ 1922–2012 white 2012–2192 grey }	Pouillet.
Wrought Iron,	2552–2733	welding heat,	Pouillet.
Copper,	average 2174		

DIMINUTION AND TENACITY OF WROUGHT IRON AT HIGH TEMPERATURES.

(Experiment at Franklin Institute, 1839. Johnson & Reeves, Com.)

C.	Fahr.	Diminution p.c. of maximum tenacity.	C.	Fahr.	Diminution p.c. of maximum tenacity.
271°			440°		0.2010
299	520°	0.0738	500	932°	0 3324
313		0.0869	508	932	0.3593
316		1.0899	554		0.4478
332	630	0.0964	599		0.5514
350		0.1047	624	1154	0.6000
378	732	0.1155	626		0.6011
389		0.1436	669		0.6622
390		0.1535	674	1245	0.6715
408		0.1589	708	1306	0.7001
410		0.1627			

TABLE OF PRESSURES.—I.

CALCULATED ACCORDING TO RULE, FOR DIFFERENT DIAMETERS AND THICKNESSES, WHEN MADE IN THE BEST MANNER IN EVERY RESPECT.

$$\text{Rule } \frac{TS(60000)\times .70\times 2t}{D \times FS} = P.$$

Boilers are not allowed to carry over 150 lbs. for Iron and 175 lbs. for Steel.

Thickness of plate in ins. or parts	36 inches diameter of boiler.	38 inches diameter of boiler.	40 inches diameter of boiler.	42 inches diameter of boiler.	45 inches diameter of boiler.	48 inches diameter of boiler.	50 inches diameter of boiler.	54 inches diameter of boiler.	60 inches diameter of boiler.	66 inches diameter of boiler.	72 inches diameter of boiler.	84 inches diameter of boiler.	86 inches diameter of boiler.	90 inches diameter of boiler.	108 inches diameter of boiler.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{4}''$	116.66	110.5	105	100	93.33	87.5	84	77.77	70	63.33	58.33	50	48.83	46.6	38.8
$\frac{5}{16}$	145.83	138.15	131.25	125	116.66	109.37	105	97.22	87.5	79.54	72.91	62.5	61.04	58.3	48.5
$\frac{6}{16}$	175	165.78	157.5	150	140	131.25	126	116.66	105	95.45	87.5	75	73.25	70	58.3
$\frac{7}{16}$	204.16	193.4	183.75	175	163.33	153.12	147	136.1	122.5	111.36	102.08	87.5	85.46	81.7	68.5
$\frac{1}{2}$	233.3	221.05	210	200	186.6	175	168	155.5	140	127.2	116.6	100	97.67	93.3	77.7
$\frac{9}{16}$	262.5	248.6	236.25	225	210	196.87	189.0	175	157.5	143.18	131.2	112.5	109	105	87.5
$\frac{3}{4}$	350	331.5	315	300	280	262	252	233.3	210	190.9	175	150	146.51	140	116.6
1	466.6	442.1	420	400	373	350	336.0	311	280.0	254.5	233.3	200.0	195.3	186.6	155.5

TABLE OF PRESSURES. II.

TABLE OF PRESSURE ALLOWABLE, ACCORDING TO THE STEAMBOAT INSPECTION ACT OF 1882. THICKNESS, DIAMETER AND PRESSURE GIVEN, AND PROPORTIONED THICKNESS, $\frac{1}{4}''$, $\frac{3}{8}''$, $\frac{5}{8}''$.

Thickness of Plate.	Diameter of boiler.	Pressure per square inch.	Thickness of Plate.	Diameter of boiler.	Pressure per square inch.	Thickness of Plate.	Diameter of boiler.	Pressure per square inch.
$\frac{1}{4}''$ = .25	28 ins.	150 lbs	$\frac{3}{8}''$ = .375	42 ins.	150 lbs.	$\frac{5}{8}''$ = .625	72 ins.	145 lbs.
" "	30	140	" "	48	131.25	" "	78	134.61
" "	36	116.6	" "	54	116.66	" "	84	125
" "	42	100	" "	60	105	" "	90	116.6
" "	48	87.5	" "	66	95.45	" "	96	109.37
" "	54	77.7	" "	72	87.5	" "	102	102.93
" "	60	70	" "	78	80.7	" "	108	97.2
" "	66	63.6	" "	84	75	" "	112	93.7
" "	72	58.33	" "	90	70	" "	120	87.5
" "	78	53.8	" "	96	65.6	" "	126	83.33
" "	84	50	" "	102	61.7	" "	132	79.5
" "	90	46.6	" "	108	58.33	" "	138	76
" "	96	43.7	" "	114	55.2	" "	144	72.9
" "	108	38.8	" "	120	52.5	" "	150	70.3
" "	114	36.8	" "	126	50	" "	156	67
" "	120	35	" "	132	47.7	" "	162	64.81

Steel one quarter more than Iron.

Rule for getting the pressure for steel boilers from this Table—Divide the pressure given for iron by 4 and this amount added to the pressure allowable on iron boilers of same dimensions will equal the pressure required for steel boilers of same dimensions.

TABLE OF AREA DIAMETER AND EQUIVALENT IN INCHES OF ROUND IRON.

Decimal equivalent in parts of an inch.	Diameter of Iron.	Area.
.0625	$\frac{1}{16}$ inch.	.00307
.125	$\frac{1}{8}$ "	.01227
.1875	$\frac{3}{16}$ "	.02761
.25	$\frac{1}{4}$ "	.04909
.3125	$\frac{5}{16}$ "	.0767
.375	$\frac{3}{8}$ "	.11045
.4375	$\frac{7}{16}$ "	.15033
.5	$\frac{1}{2}$ "	.19635
.5625	$\frac{9}{16}$ "	.2485
.625	$\frac{5}{8}$ "	.30679
.6875	$\frac{11}{16}$ "	.37122
.75	$\frac{3}{4}$ "	.44178
.8125	$\frac{13}{16}$ "	.51848
.875	$\frac{7}{8}$ "	.60132
.9375	$\frac{15}{16}$ "	.69029

FRACTIONS AND EQUIVALENT DECIMALS.

Fraction of inch.	Decimal value.	Fraction of inch.	Decimal value.
(+)			
$\frac{3}{8}$ and $\frac{3}{32}$	.46875	$\frac{1}{4}$	.25
$\frac{3}{8}$ " $\frac{1}{16}$	.4375	$\frac{1}{8}+\frac{3}{32}$	.21875
$\frac{3}{8}$ " $\frac{1}{32}$	.40625	$\frac{1}{8}+\frac{1}{16}$	.1875
$\frac{3}{8}$ " $\frac{1}{32}$	$\frac{13}{32}$=.40625	$\frac{1}{8}+\frac{1}{32}$	.15625
$\frac{3}{8}$	.375	$\frac{1}{8}$	.125
$\frac{1}{4}$ + $\frac{3}{32}$	.34375	$\frac{3}{32}$	.09375
$\frac{1}{4}$ " $\frac{1}{16}$	.3125	$\frac{1}{16}$	.0625
$\frac{1}{4}$ " $\frac{1}{32}$	.28125	$\frac{1}{32}$	.03125

TABLE I.

TENSILE STRAIN OF IRON AND STEEL RIVET BARS.

Particulars.	Mild Steel.	Taylor's Iron.	Farnley Iron.	Monkbridge B.B. Iron.	Westphalian Iron.
Diameter in inches, ...	0.625	0.625	0.75	0.75	0.75
Area in square inches, ...	0.307	0 307	0.442	0.442	0.442
1. Breaking strain, tons of	8 85	6.90	10.15	9.70	9.70
2. ....[2240 lbs	8.84	6.75	10.18	9.90	9.00
3.	8.90	6.87	.....	....	....
Average, ...	8.87	6.84	10.16	9 80	9.25
Breaking stress per sq. in.,	28.83	22.23	22.99	22.17	20.95
Reduced diameter, ...	0.343	0.406	0.500	0.531	0.515
Reduced area, ...	0.092	0.129	0.196	0.222	0.208
Reduced to original p. ct.,	30	42	44	50	47
A, Elongation per sq. in.,	0.343	0.416	0 440	0.343	0.437
B, Elongation per sq. in.,	0.206	0.279	0.278	0.225	0.250
C, Elongation per sq. in.,	0.171	0.244	0.238	0.195	0.179

A. is within the 2 inches in which the fracture occurred.
B, is within the 10 inches in which the fracture took place.
C, is outside the 2 inches in which the fracture took place.
The tensile strength was 30 per cent. more for steel than for iron; the ducility less:—

TABLE II.

SHEARING TESTS OF RIVETS, IRON AND STEEL.

Diameter of Bars ⅝ inch. Area sheared 0.6136.	In Tons of 2240 lbs.		
	Actual Shearing Strain.	Average.	Shear per square inch.
1. Yorkshire Iron (Taylor's)....	11.825	......	.....
2. Yorkshire Iron, ...	11.6	......	.....
3. Yorkshire Iron, ...	11.575	11.665	19.01
1. Steel (Brown), ...	13.45	......	.....
2. Steel, ...	13.65	......	.....
3. Steel, ...	13.725	13.61	22.18

TABLE III.

BURRS LEFT *(Dimensions in Inches.)*

	Iron.		Steel.	
	Long Axis.	Short Axis.	Long Axis.	Short Axis.
No. 1	0.616	0.588	0.616	0.583
No. 2	0.615	0.587	0.617	0.588
No. 3	0.621	0.583	0.616	0.586
No. 4	0.617	0.586	0.616	0.581

TABLE IV.

SHEARING RIVETS.

(Rivets $\frac{5}{8}$ inch diameter: Holes $\frac{11}{16}$ inch in diameter: Area sheared, .7424 square inch.)

Material.	Kind of work.	In tons of 2240 lbs.		
		Shear on piece.	Average.	Shear per sq. inch.
Yorkshire Iron	Hand	14.95	.....	....
" "	Hydraulic	15.425	.....	....
" "	Steam	16.01	15.46	20.8
Steel	Hand	18.925	.....	....
"	Hydraulic	19.320	.....	....
"	Steam	20.4	19.485	26.3

The pressure on the heads of $\frac{5}{8}$ rivets, in pounds:—

Steam rivetted,..................................82,380
Hydraulic stationary,..........................86,360
Hydraulic portable,.............................44,018
Power light blow,................................69,384
Power heavy blow,...............................115,640

Referring to the following table:—

TABLE V.

SHEARING STEEL RIVETS.

(Rivets $\frac{5}{8}$ inch diameter: Holes $\frac{11}{16}$ inch diameter: Area sheared .7424.)

Kind of Work.	Letter.	Actual Shear	Average.	Ton of 2240 lbs. per sq. in.
Steam rivetter........	a	19.5	.....	.....
	b	18.75	.....	.....
	c	18.95	19.07	25.75
Stationary hydraulic..	a	17.8	.....	.....
	b	17.05	.....	.....
	c	18.05	17.63	23.80
Portable hydraulic....	a	16.70	.....	.....
	b	17 85	.....	.....
	c	17.11	16.88	22.78
Power light blow.....	a	16.67	.....	.....
	b	16.68	.....	.....
Power heavy blow....	c	17.6	17.6	23.76

TABLE VI.

SHEARING OF STEEL RIVETS.

(Rivets $\frac{5}{8}$ inch diameter: Holes $\frac{11}{16}$ inch diameter: Area sheared .7424 square inch.)

Number.	Pressure on rivet head.	Actual shearing—Tons of 2240 lbs.	Average.
1	39,922	18.4	.....
2	83,133	18.75	.....
3	84,542	19.1	.....
4	88,299	19.337	.....
5	......	19.775	.....
6	......	19.95	.....
7	......	19.05	19.05

TABLE VII.

RIVET TESTS.

(Rivets $\frac{5}{8}$ inch diameter: Holes $\frac{11}{16}$ inch diameter: Area sheared .7424.)

Kind of work.	1 Steam.	2 Hydr'lic.	3 Hydr'lic	4 Power.	5 Power.
Pressure on head.......	83280	86360	42018	69384	115640
Breaking strain........	42717	39491	37811	37341	39424
Shearing strain........	36885	36885	36885	36885	36885
Friction	5832	2606	926	456	2539
Friction strain surface..	2916	1303	463	228	1269

The conclusions arrived at by the American Board of Engineers, who made numerous experiments at the Washington Navy Yard, are as follows, taking the tables from the "Report of the Bureau of Steam Engineering" of Naval Department, 1879.

FOR PLATES AND TIE BOLTS SCREWED THEREIN.

Thickness of sheet.	Diameter of bolt.	Thread per inch.	Bolt projected.
$\frac{1}{4}''$	$1''$	14	$\frac{1}{2}''$
$\frac{3}{8}''$	$1\frac{1}{8}''$	14	$\frac{1}{2}''$
$\frac{1}{2}''$	$1\frac{1}{4}''$	12	$\frac{1}{2}''$
$\frac{5}{8}''$	$1\frac{3}{8}''$	12	$\frac{1}{2}''$

FOR PLATES AND TIE BOLTS SCREWED THERIN.

If riveted to cone heads.		If nuts are used.	
Projection of head.	Diameter of base of cone.	Breadth of the annular bearing surface.	Dished out to a shape of
$\frac{7}{16}''$	$1\frac{5}{16}''$	$\frac{1}{16}''$	$\frac{1}{16}''$
$\frac{1}{2}''$	$1\frac{9}{16}''$	$\frac{1}{8}''$	$\frac{1}{16}''$
$\frac{9}{16}''$	$1\frac{3}{4}''$	$\frac{3}{16}''$	$\frac{3}{32}''$
$\frac{5}{8}''$	$1\frac{7}{8}''$	$\frac{1}{4}''$	$\frac{3}{32}''$

TABLE VIII.—Rivetted Joints.

Number.		How broken.	Breaking strain in pounds. Plates.	Rivets.	Average.	Break'g st'rn of solid plate per inch in width.	Brkng. str'n of specimen per inch in width.	Str'gth of seam p.c solid plate.	Width of torn section.	Strength of torn section per inch of width.	Number of rivets sheared.	Shear per rivet.	Shearing str'gth of rivet iron per rivet.	Streng. of specimen 1 p.c. normal strength. Plates.	Rivets.
			lbs.	lbs	lbs.	lbs.	lbs.		ins.	lbs.		lbs.			
1	Single-rv. lap 6¼" wide, 4 rv. ⅝ iron, holes drild	Plate & rv	57400	65300	61350	18700	9438	50.4	3.75	15300	4	16325	15810	84.1	103
2	“ “ “ “ “ punched	Plate	50800	48000	49400	18700	7600	40.6	3.5	14100	....	.....	.....	75.5	.....
3	“ “ “ “ steel, drilled	Rivets	81700	77900	79800	21700	12360	56.6	....	.....	4	19950	18440	.....	108
4	“ “ “ “ “ anneal	“	86300	83100	84700	21700	12950	59.6	....	.....	4	21175	18440	.....	115
5	“ “ “ “ “ unaneal	“	78600	91200	84900	21700	13060	60.2	....	.....	4	21225	18440	.....	115
6 {	“ “ “ “ iron hnd-wk	Plate	61400	51700	56550	18700	8700	46.2	3.75	15420	....	.....	.....	82	.....
	“ “ “ “ “ steam	Plate & rv.	56600	67100	61850	18700	9515	50.9	3.75	15420	4	16775	15810	84	106
7	“ “ “ “ “ hyd. wk	“ “	61200	67500	64350	18700	9900	53.9	3.75	16300	4	16875	15810	89.6	107
8	“ “ “ “ steel hnd. wk	“ “	72200	67400	69800	21700	10730	49.4	...	.....	4	17450	18440	.....	94.6
9	“ “ “ “ “ steam	“ “	85700	79500	82600	21700	12707	58.5	....	.....	4	20650	18440	.....	112
10	“ “ “ “ “ hyd.	“ “	87000	66400	76700	21700	11800	54.4	....	.....	4	19175	18444	.....	107
11	“ 7½ “ ¾ iron	“ “	75100	86500	80800	18700	10773	57.6	4.25	17700	4	21625	22080	97.8	97.8
12	“ “ “ “ steel	Failed	.....	.....	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
13	“ “ “ “ “	“	.....	.....	.....	.....	.....	.....	....	.....	....	.....	.....	.....	.....
14	Double. rv. “ “ 6 rv. ⅝ irn flat zigzag	Plate & rv.	82000	94400	90700	18700	12093	61.6	5.138	20500	6	15733	15810	113	99.4
15	“ “ “ “ steel	“ “	110600	116000	113300	21700	15107	70	....	.....	6	18883	18440	.....	102
16	“ “ “ 8 rv. ¾ iron sharp “	“ “	78300	87900	83100	18700	11086	59.2	4.25	19500	....	.....	.....	104	.....
17	“ “ “ “ steel “ “	“ “	96700	108200	102460	21700	13661	62.9	4.25	24700	....	.....	.....	114	.....
18	Butt sngl. cov, sngl. rv. 6¼" wide, 4 rv., ⅝" each	Iron plate	58000	58000	58000	18700	8923	46	3.75	15400	....	.....	.....	82.3	.....
19	“ “ “ “ “ “	Steelrivets	79000	78600	78800	21700	12123	55.8	....	.....	4	19700	18440	.....	107
20	“ “ dble rvt. 7½ 6 “	Iron plate	77500	78500	78000	18700	10400	55.6	5.128	19400	....	.....	.....	103	.....
21	“ “ “ “ “ “	Steelrivets	107000	114500	110750	21700	14766	68	...	.....	6	18346	18440	.....	104
22	“ dble. cov. sngl. rv., 6½ wd. 4 “	Iron plate	71500	81200	76350	18700	11746	62.7	3.75	20300	....	.....	.....	108	.....
23	“ “ “ “ “ “ “	Steel “	93000	97300	95150	21700	131000	60.4	3.75	25400	....	.....	.....	117	.....
24	“ “ “ d'ble rv. 7½ 6 “	Iron “	85300	93000	89150	18700	11886	63.5	5.138	22150	....	.....	.....	118	.....
25	“ “ “ “ “ “ “	Steel “	104000	117000	110500	21700	14740	68	5.138	27400	....	.....	.....	126	.....

PROPORTION STRENGTH OF LAP JOINTS, ETC.

Professor Kennedy's conclusion concerning the strength of rivet joints, etc., made on steel plates and rivets, are as follows:

For single rivetted lap joints the best proportions are:—

Diameter of rivets $=2.27\times$ thickness of plate.
Pitch of rivets $=2.22$ diameter.

For double rivetted lap joints:

Diameter of rivets $=2.21\times$ thickness of plate.
Pitch of rivets $=3.54$ diameter.

The rivets can be $\frac{1}{32}$ of an inch smaller than the hole. The conclusion was that with steel plates and rivets the diameter and pitch for single rivetted lap joints was such as would exclude their use for longitudinal seams and that with more than half inch plates the diameter of the rivet gets too large and the strength of the joint is thereby reduced. The strength of a single riveted lap of the proportional size given above is 55 %, and the double rivetted lap is 77 % of the plate.

The strength of plate was 70000 pounds tensile, and the rivets 51000 pounds shearing stress.

The following table made in Leeds, England, by Max Eyth and David Greig, afford some comparative data, in regard to steel and iron as given in "Engineering" 1879, an account of their experiments.

TABLE OF THE RECIPROCAL OF NUMBERS, OR THE EQUIVALENT DECIMAL FOR A FRACTION, 1 TO 75.

Fraction or number.	Decimal or reciprocal.	Fraction or number.	Decimal or reciprocal.	Fraction or number.	Decimal or reciprocal.
$\frac{1}{2}$	.5	$\frac{1}{27}$	.037037	$\frac{1}{52}$	.0192308
$\frac{1}{3}$	.333333	$\frac{1}{28}$	.0357143	$\frac{1}{53}$	.018867
$\frac{1}{4}$	.25	$\frac{1}{29}$	.034483	$\frac{1}{54}$	.018518518
$\frac{1}{5}$	.2	$\frac{1}{30}$	.0333334	$\frac{1}{55}$	.0181819
$\frac{1}{6}$	.166667	$\frac{1}{31}$	.032259	$\frac{1}{56}$	.017857
$\frac{1}{7}$	.14285714	$\frac{1}{32}$	.03125	$\frac{1}{57}$	.01754386
$\frac{1}{8}$	.125	$\frac{1}{33}$	.03036	$\frac{1}{58}$	.0172414
$\frac{1}{9}$	.1111111	$\frac{1}{34}$	.0295	$\frac{1}{59}$	.016667
$\frac{1}{10}$	.1	$\frac{1}{35}$	.028572	$\frac{1}{60}$	.0166667
$\frac{1}{11}$	.09091	$\frac{1}{36}$	.027778	$\frac{1}{61}$	.016393
$\frac{1}{12}$	.083334	$\frac{1}{37}$	.027027	$\frac{1}{62}$	.016129
$\frac{1}{13}$	.076924	$\frac{1}{38}$	.0263158	$\frac{1}{63}$	.01588
$\frac{1}{14}$	.071429	$\frac{1}{39}$	.025642	$\frac{1}{64}$	.015625
$\frac{1}{15}$	.066667	$\frac{1}{40}$	.025	$\frac{1}{65}$	.01538
$\frac{1}{16}$	.0625	$\frac{1}{41}$	.024391	$\frac{1}{66}$	.01515
$\frac{1}{17}$	.058824	$\frac{1}{42}$	.023256	$\frac{1}{67}$	.0149058
$\frac{1}{18}$	.0555556	$\frac{1}{43}$	.0232339	$\frac{1}{68}$	.014493
$\frac{1}{19}$	.052632	$\frac{1}{44}$	.022728	$\frac{1}{69}$	.01471
$\frac{1}{20}$	.05	$\frac{1}{45}$	.0222	$\frac{1}{70}$	.014286
$\frac{1}{21}$	.0476191	$\frac{1}{46}$	.0217394	$\frac{1}{71}$	.014085
$\frac{1}{22}$	.04546	$\frac{1}{47}$	.0212766	$\frac{1}{72}$	.01388
$\frac{1}{23}$	.04347	$\frac{1}{48}$	.021833	$\frac{1}{73}$	.013698
$\frac{1}{24}$	.0416667	$\frac{1}{49}$	.020408	$\frac{1}{74}$	.013512
$\frac{1}{25}$	.04	$\frac{1}{50}$	.02	$\frac{1}{75}$	.013335
$\frac{1}{26}$	.038462	$\frac{1}{51}$	.019608		

CIRCUMFERENCES OF CIRCLES—ADVANCING BY EIGHTHS.

CIRCUMFERENCES.

Diam	.0	.1/8	.1/4	.3/8	.1/2	.5/8	.3/4	.7/8
0	.0	.3927	.7854	1 178	1.570	1.063	2.356	2 748
1	3.141	3 534	3.927	4.319	4 712	5.105	5.497	5.890
2	6.283	6 675	7 068	7.461	7.854	8.246	8 639	9.032
3	9 424	9 817	10 21	10.60	10.99	11.38	11 78	12.17
4	12.56	12 95	13.35	13.74	14 13	14.52	14 92	15.31
5	15.70	16 10	16 49	16 88	17.27	17.67	18.06	18.45
6	18.84	19 24	19.63	20.02	20.42	20.81	21 20	21 59
7	21.99	22.38	22 77	23.16	23.56	23 95	24.34	24.74
8	25.13	25.52	25.91	26.31	26 70	27.09	27.48	27.88
9	28.27	28 66	29 05	29.45	29.84	30 23	30.63	31.02
10	31.41	31 80	32 20	32 59	32.98	33.37	33.77	34 16
11	34.55	34 95	35.34	35.73	36.12	36.52	36.91	37.30
12	37.69	38 09	38.48	38.87	39.27	39.66	40.05	40.44
13	40.84	41.23	41.62	42.01	42 41	42 80	43 19	43.58
14	43.98	44.37	44.76	45.16	45.55	45.94	46 33	46.73
15	47.12	47.51	47.90	48.30	48.69	49.08	49 48	49.87
16	50.26	50.65	51.05	51.44	51 83	52.22	52.62	53.01
17	53.40	53 79	54 19	54.58	54 97	55 37	55 76	56.15
18	56.54	56.94	57.33	57.72	58.11	58.51	58 90	59.29
19	59.69	60.08	60.47	60.86	61.26	61.65	62 04	62.43
20	62.83	63.22	63.61	64.01	64.40	64.79	65 18	65.58
21	65.97	66.36	66.75	67.15	67.54	67.93	68 32	68.72
22	69.11	69.50	69.90	70.29	70.68	71.07	71 47	71.86
23	72.25	72.64	73.04	73 43	73.82	74.22	74 61	75.00
24	75.39	75.79	76.18	76 57	76.96	77 36	77 75	78.14
25	78.54	78.93	79.32	79.71	80.10	80.50	80 89	81.28
26	81.68	82.07	82.46	82.85	83 25	83 64	84.03	84.43
27	84.82	85.21	85.60	86 00	86.39	86.78	87.17	87.57
28	87.96	88.35	88 75	89.14	89.53	89.92	90 32	90.71
29	91.10	91.49	91.89	92.28	92.67	93 06	93 46	93.85
30	94.24	94 64	95.03	95.42	95 81	96 21	96 60	96.99
31	97.39	97.78	98 17	98.57	98 96	99.35	99 75	100.14
32	100.53	100.92	101.32	101.71	102.10	102 49	102.89	103.29
33	103 67	104.07	104 46	104.85	105.24	105.64	106.03	106.42
34	106.81	107.21	107.60	107.99	108 39	108 78	109 17	109 56
35	109.96	110.35	110 74	111.13	111.53	111 92	112.31	112.71
36	113.10	113 49	113.88	114 28	114.67	115.06	115 45	115.85
37	116.24	116.63	117.02	117.42	117.81	118 20	118 60	118 99
38	119.38	119.77	120.17	120.56	120.95	121.34	121.74	122.13
39	122.52	122 92	123 31	123 70	124.09	124.49	124 88	125.27
40	125.66	126.06	126.45	126 84	127.24	127.36	128.02	128 41
41	128.81	129 20	129.59	129.98	130.38	130.77	131 16	131.55
42	131.95	132 34	132.73	133 13	133.52	133.91	134 30	134 70
43	135.09	135.48	135.87	136.27	136.66	137.05	137 45	137.84
44	138.23	138 62	139.02	139 41	139 80	140 19	140 59	140.98
45	141 37	141 76	142.16	142 55	142 94	143.34	143 73	144 12

AREAS OF CIRCLES—ADVANCING BY EIGHTHS.

AREAS.

Diam.	.0	.1/8	.1/4	.3/8	.1/2	.5/8	.3/4	.7/8
0	.0	.0122	.0490	.1104	.1963	.3068	.4417	.6013
1	.7854	.9940	1.227	1.484	1.767	2.073	2.405	2.761
2	3.1416	3.546	3.976	4 430	4.908	5.411	5.939	64.91
3	7.068	7.669	8.295	8 946	9.621	10.32	11.04	11.79
4	12.56	13.36	14.18	15.03	15.90	16.80	17.72	18.66
5	19.63	20.62	21.64	22.69	23.75	24.85	25.96	27.10
6	28.27	29.46	30.67	31.91	33.18	34.47	35.78	37.12
7	38.48	39.87	41.28	42.71	44.17	45.66	47.17	48.70
8	50.26	51.84	53.45	55.08	56.74	58.42	60.13	61.86
9	63.61	65.39	67.20	69.02	70.88	72.75	74.69	76.58
10	78.54	80.51	82.51	84.54	86.59	88.66	90.76	92.88
11	95.03	97.20	99.40	101.6	103.8	106.1	108.4	110.7
12	113.0	115.4	117.8	120.2	122.7	125.1	127.6	130.1
13	132.7	135.2	137.8	140.5	143.1	145.8	148 4	151.2
14	153.9	156.6	159.4	162.2	165.1	167.9	170.8	173.7
15	176.7	179.6	182.6	185 6	188.6	191.7	194.8	197.9
16	201.0	204.2	207.3	210.5	213.8	217.0	220.3	223.6
17	226.9	230.3	233.7	237.1	240.5	243 9	247 4	250.9
18	254.4	258.0	261.5	265.1	268.8	272.4	276.1	279.8
19	283.5	287.2	291.0	294.8	298.6	302.4	306 3	310.2
20	314.1	318.1	322.0	326.0	330.0	334.1	338.1	342.2
21	346.3	350.4	354.6	358.8	363.0	367.2	371.5	375.8
22	380.1	384.4	388.8	393.2	397.6	402.0	406.4	410.9
23	415.4	420 0	424.5	429.1	433·7	438.3	443.0	447.6
24	452.3	457.1	461.8	466.6	471.4	476.2	481.1	485.9
25	490.8	495.7	500.7	505.7	510.7	515.7	520.7	525.8
26	530.9	536.0	541.1	546.3	551.5	556.7	562.0	567.2
27	572.5	577.8	583.2	588.5	593.9	599.3	604.8	610.2
28	615.7	621.2	626 7	632.3	637.9	643.5	649.1	654.8
29	660.5	666.2	671.9	677.7	683 4	689.2	695.1	700.9
30	706.8	712.7	718.6	724.6	730.6	736.6	742.6	748.6
31	754.8	760.9	767.0	773.1	779.3	785.5	791.7	798.0
32	804.3	810.6	816.9	823 2	829.6	836.0	842.4	848.8
33	855.3	861.8	868 3	874 9	881.4	888.0	894 6	901.3
34	907.9	914.7	921.3	928.1	934.8	941.6	948.4	955.3
35	962.1	969.0	975.9	982.8	989.8	996.8	1003.8	1010.8
36	1017.9	1025.0	1032.1	1039.2	1046.3	1053.5	1060.7	1068.0
37	1075.2	1082.5	1089.8	1097.1	1104.5	1111.8	1119.2	1126.7
38	1134.1	1141.6	1149.1	1156.6	1164.2	1171.7	1179.3	1186.9
39	1194.6	1202.3	1210.0	1217.7	1225.4	1233.2	1241.0	1248.8
40	1256.6	1264.5	1272 4	1280.3	1288.2	1296.2	1304.2	1312.2
41	1320.3	1328.3	1336.4	1344.5	1352.7	1360.8	1369.0	1377.2
42	1385.4	1393.7	1402.0	1410.3	1418.6	1427.0	1435.4	1443.8
43	1452.2	1460.7	1469.1	1477.6	1486.2	1494.7	1503.3	1511.9
44	1520.5	1529.2	1537.9	1546.6	1555.3	1564.0	1572.8	1581.6
45	1590.4	1599.3	1608.2	1617.0	1626.0	1634.9	1643.9	1652.9

SPECIFIC GRAVITY AND WEIGHTS OF VARIOUS SUBSTANCES.

Name of substance.	WEIGHTS.			Specific gravity.
	Per cubic foot.	Per square foot, 1 inch thick.	Per cubic inch.	
Water, pure	62.3	5.19	.036	1.000
Water, sea	64.3	5.36	.037	1 028
Wrought iron	480	40.00	.277	7.70
Cast Iron	450	37.50	.260	7.20
Steel	490	40.84	.283	7.84
Lead	710	59.16	.410	11.36
Copper, rolled	548	45.66	.317	8.80
Brass, rolled	524	43 66	.302	8.40
Sand	98	8.23	.057	1 57
Clay	120	10.00	.069	1.92
Brickwork, common	120	10 00	.069	1.92
Brickwork, close joints	140	11.66	.081	2.24
Limestone	168	18.00	.124	2.68
Glass	156	13.00	.090	2.49
Pine, white	30	2.50	.017	.48
Pine, yellow	35	2.91	.019	.56
Hemlock	25	2.08	.015	.40
Maple	49	4.08	.028	.78
Oak, white	50	4.16	.030	80
Walnut	41	3.41	.023	.65

COAL PRODUCTION OF THE WORLD.

(By James MacFarlane, author of "The Coal Regions of America.")

YEAR.	COUNTRIES.	TONS.
1872	United States	41,000,000
1872	Nova Scotia	880,950
1872	Great Britain	123,386,758
1872	France	15.000,000
1871	Belgium	13.773,176
1870	Austria	6.443.575
1870	Prussia	23,316,238
1862	Poland	112,500
1867	Russia	259,5[illegible]
1869	Spain	593,05[illegible]
1868	India	547,971
1869	New South Wales	919,522
	Total reports	226.233,244
	Chili, China, New Zealand, Pacific Coast, &c., estimated	1,800,000
	Total of the World	228,033,244

ANNUAL MAKE OF IRON AND STEEL IN THE WORLD.

YEAR.	COUNTRIES.	TONS.
1872	Great Britain	6,741.929
1873	United States	2,695,000
1871	Germany	1,664,802
1873	France	1,381,000
1872	Belgium	652,565
1871	Austria with Hungary	424,606
1871	Russia	354,000
1872	Sweden	322,000
1872	Luxenburg	300,000
	Canada	100,000
1872	Italy	73,709
1870	Spain	54,007
	Norway	20,000
	South America	15,000
1871	Japan	9,370
1872	Switzerland	7.500
	Asia	40,000
	Africa	20,000
	Australasia	10,000
	Total	14,885,488

AREAS OF CIRCLES, FROM $\frac{1}{64}$ TO 26. ADVANCING BY AN EIGHTH.

Diam	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
1/64	.000192	.5/8	10.3206	.3/8	55.0884	.1/8	135.297
1/32	.000767	.3/4	11.0447	.1/2	56.7451	.1/4	137.887
1/16	.003068	.7/8	11.7933	.5/8	58.4264	.3/8	140.501
1/8	.012272	4.	12.5664	.3/4	60.1322	.1/2	143.139
3/16	.027612	.1/8	13.3641	.7/8	61.8625	.5/8	145.802
1/4	.049087	.1/4	14.1863	9.	63.6174	.3/4	148.49
5/16	.076699	.3/8	15 033	.1/8	65.3968	.7/8	151.202
3/8	.110447	.1/2	15.9043	.1/4	67.2008	14.	153.938
7/16	.15033	.5/8	16.8002	.3/8	69 0293	.1/8	156.7
1/2	.19635	.3/4	17.7206	.1/2	70 8823	.1/4	159.485
9/16	.248505	.7/8	18.6655	.5/8	72.7599	.3/8	162.296
5/8	.306796	5.	19.635	.3/4	74 6621	.1/2	165.13
11/16	.371224	.1/8	20.629	.7/8	76.5888	.5/8	167.99
3/4	.441787	.1/4	21.6476	10.	78.54	.3/4	170.874
13/16	.518487	.3/8	22.6907	.1/8	80.5158	.7/8	173.782
7/8	.601322	.1/2	23.7583	.1/4	82.5161	15.	176.715
15/16	.690292	.5/8	24.8505	.3/8	84.5409	.1/8	179.673
1.	.7854	.3/4	25.9673	.1/2	86.5903	.1/4	182.655
.1/8	.99402	.7/8	27.1086	.5/8	88 6643	.3/8	185.661
.1/4	1.2272	6.	28.2744	.3/4	90.7628	.1/2	188.692
.3/8	1.4849	.1/8	29.4644	.7/8	92.8858	.5/8	191.748
.1/2	1.7671	.1/4	30.6797	11.	95.0334	.3/4	194 828
.5/8	2.0739	.3/8	31.9191	.1/8	97.2055	.7/8	197.933
.3/4	2.4053	.1/2	33.1831	.1/4	99.4022	16.	201.062
.7/8	2.7612	.5/8	34.4717	.3/8	101.6234	.1/8	204.216
2.	3.1416	.3/4	35.7848	.1/2	103.8691	.1/4	207.395
.1/8	3.5466	.7/8	37.1224	.5/8	106.1394	.3/8	210.598
.1/4	3.9761	7.	38.4846	.3/4	108.4343	.1/2	213.825
.3/8	4.4301	.1/8	39.8713	.7/8	110.7537	.5/8	217.077
.1/2	4.9087	.1/4	41.2826	12.	113.098	.3/4	220.354
.5/8	5 4119	.3/8	42.7184	.1/8	115 446	.7/8	223.655
.3/4	5.9396	.1/2	44.1787	.1/4	117.859	17.	226.981
.7/8	6.4918	.5/8	45.6636	.3/8	120.277	.1/8	230.331
3.	7.0686	.3/4	47.1731	.1/2	122 719	.1/4	233.706
.1/8	7.6699	.7/8	48.7071	.5/8	125.185	.3/8	237.105
.1/4	8.2958	8.	50.2656	.3/4	127.677	.1/2	240.529
.3/8	8.9462	.1/8	51.8487	.7/8	130.192	.5/8	243.977
.1/2	9.6211	.1/4	53.4563	13.	132.733	.3/4	247.45

Areas of Circles, From $\frac{1}{64}$ to 26. Advancing by an Eighth.—(Continued.)

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
.7/8	250.948	20.	314.16	.1/8	384.466	.1/8	457.115
18.	254.47	.1/8	318.099	.1/4	388.822	.1/4	461.864
.1/8	258.016	.1/4	322.063	.3/8	393.203	.3/8	466.638
.1/4	261.587	.3/8	326.051	.1/2	397.609	.1/2	471.436
.3/8	265.183	.1/2	330.064	.5/8	402.038	.5/8	476.259
.1/2	268.803	.5/8	334.102	.3/4	406.494	.3/4	481.107
.5/8	272.448	.3/4	338.164	.7/8	410.973	.7/8	485.979
.3/4	276.117	.7/8	342.25	23.	415.477	25.	490.875
.7/8	279.811	21.	346.361	.1/8	420.004	.1/8	495.796
19.	283.529	.1/8	350.497	.1/4	424.558	.1/4	500.742
.1/8	287.272	.1/4	354.657	.3/8	429.135	.3/8	505.712
.1/4	291.04	.3/8	358.842	.1/2	433.737	.1/2	510.706
.3/8	294.832	.1/2	363.051	.5/8	438.364	.5/8	515.726
.1/2	298.648	.5/8	367.285	.3/4	443.015	.3/4	520.769
.5/8	302.489	.3/4	371.543	.7/8	447.69	.7/8	525.838
.3/4	306.355	.7/8	375.826	.24	452.39	26.	530.93
.7/8	310.245	22.	380.134				

IRON RIVETS.

WEIGHT PER 100.

Length under head.	DIAMETERS.						
	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
1	1.895	4.848	9.66	16.79	26.49	39.3	55.2
$\frac{1}{8}$	2.067	5.235	10.34	17.86	27.99	41.4	57.9
$\frac{1}{4}$	2.238	5.616	11.04	18.96	29.61	43.5	60.7
$\frac{3}{8}$	2.410	6.003	11.73	20.03	31.13	45.6	63.4
$\frac{1}{2}$	2.582	6.402	12.43	21.04	32.74	47.8	66.2
$\frac{5}{8}$	2.754	6.789	13.12	22.11	34.25	49.9	68.9
$\frac{3}{4}$	2.926	7.179	13.81	23.21	35.86	52.0	71.7
$\frac{7}{8}$	3.098	7.566	14.50	24.28	37.37	54.1	74.4
2	3.269	7.956	15.19	25.48	38.99	56.3	77.2
$\frac{1}{8}$	3.144	8.343	15.88	26.56	40.40	58.4	79.9
$\frac{1}{4}$	3.613	8.733	16.57	27.65	42.11	60.5	82.7
$\frac{3}{8}$	3.785	9.120	17.26	28.73	43.67	62.6	85.4
$\frac{1}{2}$	3.957	9.511	17.95	29.82	45.24	64.8	88.2
$\frac{5}{8}$	4.129	9.898	18.64	30.90	46.80	66.9	90.9
$\frac{3}{4}$	4.301	10.29	19.33	31.99	48.36	69.0	93.7
$\frac{7}{8}$	4.473	10.67	20.02	33.08	49.92	71.1	96.4
3	4.644	11.06	20.71	34.18	51.49	73.3	99.2
$\frac{1}{8}$	4.816	11.44	21.40	35.27	53.05	75.4	101.9
$\frac{1}{4}$	4.988	11.84	22.09	36.35	54.61	77.5	104.7
$\frac{3}{8}$	5.160	12.23	22.78	37.44	56.17	79.6	107.4
$\frac{1}{2}$	5.332	12.62	23 48	38.52	57.74	81.8	110.2
$\frac{5}{8}$	5.504	13.01	24 17	39.60	59.30	83.9	112.9
$\frac{3}{4}$	5.676	13.39	24.86	40.69	60.86	86.0	116.7
$\frac{7}{8}$	5.848	13.78	25.55	41.78	62.42	88.1	119.4
4	6.019	14.17	26.24	42.87	63.99	90.3	121.2
$\frac{1}{8}$	6.191	14.56	26.93	43.94	65.55	92.4	123.9
$\frac{1}{4}$	6.363	14.95	27.62	45.01	67.11	94.5	126.6
100 Heads.	.519	1.74	4.14	8.10	13.99	22.27	33.15

Length of rivet required to make one head = $1\frac{1}{2}$ diameters of round bar.

WEIGHT OF WROUGHT IRON.

(TRAUTWINE.)

Thickness or diameter. Inches.	Thickness or diameter. In decimals of a foot.	Weight of a square foot. Lbs.	Weight per foot square bar. Lbs.	Weight per foot round bar. Lbs.
3 1/8	.2604	126 3	32 89	25 83
1/4	.2708	131 4	25.57	27.94
3/8	.2813	136 4	38 37	30.13
1/2	.2917	141 5	41 26	32 41
5/8	.3021	146 5	44 26	34.76
3/4	.3125	151.6	47 37	37 20
7/8	.3229	156 6	50 57	39.72
4	.3333	161.7	53 89	42 33
1/8	.3438	166.7	57.31	45 01
1/4	.3542	171 8	60 84	47 78
3/8	.3646	176.8	64 47	50 63
1/2	.3750	181.9	68.20	53 57
5/8	.3854	186 9	72 05	56 59
3/4	.3958	192 0	95.99	59 69
7/8	.4063	197.0	80.05	62 87
5	.4167	202.1	84 20	66 13
1/8	.4271	207.1	88 47	69 48
1/4	.4375	212.2	92 83	72 91
3/8	.4479	217.2	97.31	76 43
1/2	.4583	222.3	101.9	80.02
5/8	.4688	227.3	106.6	83.70
3/4	.4792	232.4	111.4	87.46
7/8	.4896	237.5	116.3	91 31
6	.5000	242.5	121.3	95.23
1/4	.5208	252.6	131 6	103.3
1/2	.5417	262 7	142 3	111.8
3/4	.5625	272.8	153.5	120.5
7	.5833	282 9	165.0	129 6
1/4	.6042	293 0	177.0	139 0
1/2	.6250	303.1	189 5	148 8
3/4	.6458	313 2	202.3	158.9
8	.6667	323 3	215 6	169.3
1/4	.6875	333 4	229 3	180.1
1/2	.7083	343.5	243 4	191.1
3/4	.7292	353 6	247.9	202 5
9	.7500	363 8	272.8	214 3
1/4	.7708	373 9	288.2	226.3
1/2	.7917	384.0	304 0	238 7
3/4	.8125	394.1	320 2	251.5
10	.8333	404.2	336.8	264 5
1/2	.8750	424.4	371 3	291.6
11	.9167	444.6	407.5	220.1
1/2	.9583	464.8	445.4	349.8
12	1 Foot.	485	485	380 9

LINEAR EXPANSION OF METALS.

	Between 0° and 100° C.	For 1° C.	For 1° Fahr.
Zinc,	0.00294	....	....
Lead,	0.00284	....	....
Tin,	0.00222	....	....
Copper, yellow,	0.00188	....	....
" red,	0.00171	....	....
*Forged iron,	0.00122	.0000122	.00000677
†Steel,	0.00114	.0000114	.00000633
*Cast iron,	0.00111	.0000111	.00000616

For a change of 100° Fahr. a bar of iron 1475′ long will extend 1 foot. Similarly, a bar 100 feet long will extend .0678 foot, or .8136 inch.

According to the experiments of DuLong & Petit, we have the mean expansion of iron, copper and platinum between 0° and 100° C., and 0° and 300° C., as below:

	From 0° to 100° C.	0° to 300° C.
Iron,	0.00180	0.00146
Copper,	0.00171	0.00188
Platinum,	0.00884	0.00918

The law for the expansion of iron, steel and cast iron at very high temperatures, according to Rinman, is a follows:

	From 25° to 525° C. red heat = 500° C.	For 1° C.	1° Fahr.
Iron,	.00714	.0000143=	.0000080
Steel,	.01071	.0000214=	.0000119
Cast iron,	.01250	.0000250=	.0000139

	From 25° to 1300° nascent white = 1275° C.		
Iron,	.01250	.00000981=	.00000545
Steel,	.01787	.00001400=	.00000777
Cast iron,	.02144	.00001680=	.00000933

	From 500° to 1500° dull red to white heat = 1000° C. difference.		
Iron,	.00535	.00000535=	.0000030
Steel,	.00714	.00000714=	.0000040
Cast iron,	.00893	.00000893=	.0000050

RATIO OF EXPANSION IN HUNDRED PARTS, ASSUMING FORGE IRON TO EXPAND BETWEEN 0° AND 100° C. = .00122.

	From 0° to 100°	25° to 525°	25° to 1300°	500° to 1500°
Iron,	100 per ct.	117 per ct.	80 per ct.	44 per ct.
Steel,	93 "	175 "	114 "	58 "
Cast Iron,	91 "	205 "	137 "	73 "

*Laplace & Lavoisier. †Ramsden.

WEIGHT OF FLAT BAR IRON.

PER FOOT.

Width in inches.	Thickness in inches.											
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$6\frac{1}{4}$	1 31	2 63	3 95	5 27	6 58	7 90	9 21	10 53	13.16	15.79	18.42	21.05
$6\frac{1}{2}$	1 36	2 73	4 10	5 47	6 84	8 21	9 58	10 94	13 68	16.42	19.16	21.88
$6\frac{3}{4}$	1.42	2 84	4 26	5 69	7 10	8 53	9 95	11 36	14 21	17.05	19.90	22.73
7	1 47	2 94	4 42	5 90	7 36	8 84	10 32	11 79	14.74	17.68	20 64	23.58
$7\frac{1}{4}$	1 53	3 05	4 58	6 11	7 63	9 16	10 68	12 21	15 26	18.32	21 37	24.42
$7\frac{1}{2}$	1 58	3 16	4 74	6 32	7 90	9 48	11.06	12 64	15.78	18.94	22 11	25 28
$7\frac{3}{4}$	1 63	3 26	4 90	6 53	8 16	9 79	11 42	13 06	16.31	19.57	22 84	26 12
8	1 68	3 36	5 05	6.74	8 [illegible]2	10.10	11 78	13 48	16.84	20 20	23 58	26 94
$8\frac{1}{4}$	1 74	3 47	5 21	6 95	8 68	10 42	12 16	13 89	17.37	20 84	24.32	27.79
$8\frac{1}{2}$	1 79	3 58	5 36	7 16	8 94	10 74	12 52	14.32	17.90	21.48	25.06	28.63
$8\frac{3}{4}$	1 84	3.68	5 53	7 37	9 21	11 05	12 89	14 74	18 42	22 10	25.79	29 47
9	1.90	3 79	5 68	7 58	9 58	11 36	13 26	15 16	18.95	22.75	26 52	30 32
$9\frac{1}{4}$	1 95	3 90	5 84	7 79	9.74	11 68	13 63	15 58	19 47	23 38	27 26	31 16
$9\frac{1}{2}$	2 00	4 00	6 00	8 00	10 00	12.00	14 00	16.00	20.00	24.00	28.00	32.00
$9\frac{3}{4}$	2 05	4 11	6 16	8 21	10.26	12 32	14 37	16 42	20.53	24 63	28 74	32 84
10	2 10	4 21	6 32	8 42	10.52	12 64	14 74	16 84	21.05	25.26	29 48	33.68
$10\frac{1}{4}$	2 16	4.32	6 48	8.63	10.79	12 95	15 11	17 26	21.58	25.89	30.21	34.52
$10\frac{1}{2}$	2 21	4 41	6 64	8 84	11.05	13 26	15 48	17 68	22.10	26.52	30.95	35.36
$10\frac{3}{4}$	2 26	4 53	6.79	9 05	11 32	13 58	15 84	18 10	22 63	27.16	31 68	36 21
11	2 32	4 64	6 95	9.26	11 58	13 90	16 21	18 52	2[illegible] 16	27.78	32 42	37 04
$11\frac{1}{4}$	2 37	4 74	7.11	9.47	11 85	14 21	16 58	18 94	2[illegible] 38	28 42	33.15	37 89
$11\frac{1}{2}$	2 42	4 84	7 26	9.68	12 10	14 52	16 94	19 36	24.20	29 06	33 90	38 74
$11\frac{3}{4}$	2 47	4.94	7 42	9 89	12 37	14.84	17 31	19 78	24.73	29 69	34.6[illegible]	39 56
12	2 52	5 05	7 58	10.10	12 64	15 16	17 68	20.20	25.26	30 32	35.36	40 40

TABLE OF HYPERBOLIC LOGARITHMS.

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
1.01	.0099503	1.40	.3364722	1.79	.5822156
1.02	.0198026	1.41	.3435897	1.80	.5877866
1.03	.0295588	1.42	.3506568	1.81	.5933268
1.04	.0392207	1.43	.3576744	1.82	.5988365
1.05	.0487902	1.44	.3646431	1.83	.6043159
1.06	.0582689	1.45	.3715635	1.84	.6097655
1.07	.0676586	1.46	.3784364	1.85	.6151856
1.08	.0769610	1.47	.3852624	1.86	.6205764
1.09	.0861777	1.48	.3920420	1.87	.6259384
1.10	.0953102	1.49	.3987761	1.88	.6312717
1.11	.1043600	1.50	.4054651	1.89	.6365768
1.12	.1133287	1.51	.4121096	1.90	.6418538
1.13	.1222176	1.52	.4187103	1.91	.6471032
1.14	.1310283	1.53	.4252677	1.92	.6523251
1.15	.1397619	1.54	.4317824	1.93	.6575200
1.16	.1484200	1.55	.4382549	1.94	.6626879
1.17	.1570037	1.56	.4446858	1.95	.6678293
1.18	.1655144	1.57	.4510756	1.96	.6729444
1.19	.1739533	1.58	.4574248	1.97	.6780335
1.20	.1823215	1.59	.4637340	1.98	.6830968
1.21	.1962030	1.60	.4700036	1.99	6881346
1.22	.1988508	1.61	.4762341	2.00	.6931472
1.23	.2070141	1.62	.4824261	2.01	.6981347
1.24	.2151113	1.63	.4885800	2.02	.7030974
1.25	.2231435	1.64	.4946962	2.03	.7080357
1.26	.2341117	1.65	.5007752	2.04	.7129497
1.27	.2390169	1.66	.5068175	2.05	.7178397
1.28	.2468600	1.67	.5128236	2.06	.7227059
1.29	.2546422	1.68	.5187937	2.07	.7275485
1.30	.2623642	1.69	.5247285	2.08	.7323678
1.31	.2700271	1.70	.5306282	2.09	.7316470
1.32	.2776317	1.71	.5364933	2.10	.7419373
1.33	.2851789	1.72	.5423242	2.11	.7466879
1.34	.2926696	1.73	.5481214	2.12	.7514160
1.35	.3001045	1.74	.5538851	2.13	.7561219
1.36	.3074846	1.75	.5596157	2.14	.7608058
1.37	.3148107	1.76	.5653138	2.15	.7654678
1.38	.3220834	1.77	.5709795	2.16	.7701082
1.39	.3293037	1.78	.5766133	2.17	.7747271

Table of Hyperbolic Logarithms.—(Continued).

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
2.18	.7793248	2.57	.9439058	2.96	1.0851892
2.19	.7839015	2.58	.9477893	2.97	1.0885619
2.20	.7884573	2.59	.9516578	2.98	1.0919233
2.21	.7929025	2.60	.9555114	2.99	1.0952733
2.22	.7975071	2.61	.9593602	3.00	1.0986123
2.23	.8021015	2.62	.9631743	3.01	1.1919400
2.24	.8064758	2.63	.9669838	3.02	1.1052568
2.25	.8109302	2.64	.9707789	3.03	1.1085626
2.26	.8153648	2.65	.9745596	3.04	1.1118575
2.27	.8197798	2.66	.9783261	3.05	1.1111415
2.28	.8241754	2.67	.9820784	3.06	1.1184149
2.29	.8285518	2.68	.9858167	3.07	1.1216775
2.30	.8329091	2.69	.9895411	3.08	1.1249295
2.31	.8372475	2.70	.9932517	3.09	1.1281710
2.32	.8415671	2.71	.9969486	3.10	1.1314021
2.33	.8458682	2.72	1.0006318	3.11	1.1346227
2.34	.8501509	2.73	1.0043015	3.12	1.1378330
2.35	.8544153	2.74	1.0079579	3.13	1.1410330
2.36	.8586616	2.75	1.0116008	3.13	1.1442227
2.37	.8628899	2.76	1.0152306	3.15	1.1474024
2.38	.8671004	2.77	1.0188473	3.16	1.1505720
2.39	.8712933	2.78	1.0224509	3.17	1.1537315
2.40	.8754687	2.79	1.0260415	3.18	1.1568811
2.41	.8796267	2.80	1.0296194	3.19	1.1600209
2.42	.8837675	2.81	1.0331844	3.20	1.1631508
2.43	.8878912	2.82	1.0367368	3.21	1.1662709
2.44	.8919980	2.83	1.0402766	3.22	1.1693813
2.45	.8960880	2.84	1.0438040	3.23	1.1724821
2.46	.9001613	2.85	1.0473189	3.24	1.1755733
2.47	.9042181	2.86	1.0508216	3.25	1.1786549
2.48	.9082585	2.87	1.0543120	3.26	1.1817271
2.49	.9122826	2.88	1.0577902	3.27	1.1847899
2.50	.9162907	2.89	1.0612564	3.28	1.1878434
2.51	.9202827	2.90	1.0647107	3.29	1.1908875
2.52	.9242589	2.91	1.0681530	3.30	1.1939224
2.53	.9282193	2.92	1.0715836	3.31	1.1969481
2.54	.0321640	2.93	1.0750024	3.32	1.1999647
2.55	.9360933	2.94	1.0784095	3.33	1.2029722
2.56	.9400072	2.95	1.0818051	3.34	1.2059707

Table of Hyperbolic Logarithms—(Continued.)

Number.	Logarithms.	Number.	Logarithms.	Number.	Logarithms.
4.52	1.5085119	4.91	1.5912739	5.30	1.6677068
4.53	1.5107219	4.92	1.5933085	5.31	1.6695918
4.54	1.5129269	4.93	1.5953389	5.32	1.6714733
4.55	1.5151272	4.94	1.5973653	5.33	1.6733512
4.56	1.5173226	4.95	1.5993875	5.34	1.6752256
4.57	1.5195132	4.96	1.6014057	5.35	1.6770965
4.58	1.5216990	4.97	1.6034198	5.36	1.6789639
4.59	1.5238800	4.98	1.6054298	5.37	1.6808278
4.60	1.5260563	4.99	1.6074358	5.38	1.6826882
4.61	1.5282278	5.00	1.6094379	5.39	1.6845453
4.62	1.5303947	5.01	1.6114359	5.40	1.6863989
4.63	1.5325568	5.02	1.6134300	5.41	1.6882491
4.64	1.5347143	5.03	1.6154200	5.42	1.6900958
4.65	1.5368672	5.04	1.6174060	5.43	1.6919391
4.66	1.5390154	5.05	1.6193882	5.44	1.6937790
4.67	1.5411590	5.06	1.6213664	5.45	1.6956155
4.68	1.5432981	5.07	1.6233408	5.46	1.6974487
4.69	1.5454325	5.08	1.6253112	5.47	1.6992786
4.70	1.5475625	5.09	1.6272778	5.48	1.7011051
4.71	1.5496879	5.10	1.6292405	5.49	1.7029282
4.72	1.5518087	5.11	1.6311994	5.50	1.7047481
4.73	1.5539252	5.12	1.6331544	5.51	1.7065646
4.74	1.5560371	5.13	1.6351056	5.52	1.7083778
4.75	1.5581446	5.14	1.6370530	5.53	1.7101878
4.76	1.5602476	5.15	1.6389967	5.54	1.7119944
4.77	1.5623462	5.16	1.6409365	5.55	1.7137979
4.78	1.5644405	5.17	1.6428726	5.56	1.7155981
4.79	1.5665304	5.18	1.6448050	5.57	1.7173950
4.80	1.5686159	5.19	1.6463336	5.58	1.7191887
4.81	1.5706971	5.20	1.6486586	5.59	1.7209792
4.82	1.5727739	5.21	1.6505789	5.60	1.7227666
4.83	1.5748464	5.22	1.6524974	5.61	1.7245507
4.84	1.5769147	5.23	1.6544112	5.62	1.7263316
4.85	1.5789787	5.24	1.6563214	5.63	1.7281004
4.86	1.5810384	5.25	1.6582280	5.64	1.7298840
4.87	1.5830939	5.26	1.6601310	5.65	1.7316555
4.88	1.5851452	5.27	1.6620303	5.66	1.7334238
4.89	1.5870923	5.28	1.6639260	5.67	1.7351891
4.90	1.5892352	5.29	1.6658182	2.68	1.7369512

TABLES OF SIZES OF SQUARE AND HEXAGON NUTS.

Franklin Institute standard sizes Square and Hexagon Nuts. Number of each size in 100 lbs. These Nuts are chamfered and trimmed.

HOOPES & TOWNSEND, PHILADELPHIA.

Width.	Thickness.	Hole.	Size of Bolt.	Number of Square.	Number of Hexagon.
1/2	1/4	13/64	1/4	8140	9390
19/32	5/16	1/4	5/16	3000	6200
11/16	3/8	5/16	3/8	2320	3120
25/32	7/16	11/32	7/16	1940	2200
7/8	1/2	13/32	1/2	1180	1350
31/32	9/16	29/64	9/16	920	1000
1 1/16	5/8	33/64	5/8	738	830
1 1/4	3/4	5/8	3/4	420	488
1 7/16	7/8	23/32	7/8	280	309
1 5/8	1	27/32	1	180	216
1 13/16	1 1/8	15/16	1 1/8	130	148
2	1 1/4	1 1/16	1 1/4	96	111
2 3/16	1 3/8	1 5/32	1 3/8	70	85
2 3/8	1 1/2	1 9/32	1 1/2	60	70

HEXAGON NUTS, REGULAR SIZES.

Width.	Thickness.	Hole.	Size of Bolt.	Number in 100 lbs.
1/2	1/4	7/32	1/4	8600
5/8	5/16	17/64	5/16	4260
3/4	3/8	21/64	3/8	2500
3/4	7/16	3/8	7/16	2180
1	9/16	7/16	1/2	900
1	9/16	15/32	9/16	880
1 1/8	3/4	17/32	5/8	535
1 3/8	7/8	21/32	3/4	295
1 1/2	1	3/4	7/8	224
1 3/4	1 1/8	27/32	1	150
2	1 3/8	15/16	1 1/8	100
2	1 3/8	1 1/16	1 1/4	96
2 1/4	1 1/2	1 3/16	1 3/8	72
2 3/4	1 5/8	1 5/16	1 1/2	43

SQUARE NUTS, REGULAR SIZES.

Width.	Thickness.	Hole.	Size of Bolt.	Number in 100 lbs.
1/2	1/4	7/32	1/4	6680
5/8	5/16	17/64	5/16	3540
3/4	3/8	21/64	3/8	2050
7/8	3/8	3/8	7/16	1380
1	7/16	7/16	1/2	940
1 1/8	1/2	1/2	9/16	650
1 1/4	1/2	17/32	5/8	410
1 3/8	5/8	21/32	3/4	270
1 1/2	3/4	3/4	7/8	215
1 3/4	1	27/32	1	140
2	1 1/8	15/16	1 1/8	95
2 1/4	1 1/4	1 1/16	1 1/4	72
2 1/2	1 3/8	1 1/16	1 3/8	45
3	1 1/2	1 3/16	1 1/2	32

TABLES OF SIZES OF WASHERS AND BOLTS WITH SQUARE HEADS AND NUTS.

BOLTS.—Weight of 100 of the Enumerated Sizes.

HOOPES & TOWNSEND, PHILADELPHIA.

Lengths.	¼ in.	⅜ in.	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in
Inch.								
1¼	4.16	10.62	23.87	39.31	....	......	...	...
1¾	4.22	11.72	25.06	41.38	.....	......	...	...
2	4.75	12.38	26.44	45.69	73 62	......	...	...
2¼	5.34	12 90	28.62	49.50	76	......	...	...
2½	5.97	14.69	29.50	51.25	79.75	......	...	...
2¾	6.50	16.47	31.16	53	83	......	...	...
3	....	17.87	32.44	56	85.38	127.25	...	...
3½	....	18 94	39.75	63.12	93.44	140.56	...	...
4	....	20.59	42.50	74.87	108.12	148 37	228	296
4½	....	21.69	44.87	79.62	113.12	158.76	239	310
5	....	23.62	48 81	83	122	167.25	250	324
5½	....	25.81	51.38	87.88	128.62	174.88	261	338
6	....	26.87	53.31	92 38	131.75	204.25	272	352
6½	....	.....	56.87	96.88	139.56	214.69	283	366
7	....	.....	59 12	99.87	145.50	228.44	294	370
7½	....	.....	61.87	105.75	150.88	235.31	305	384
8	....	.....	64.44	109.50	157.12	239.88	316	398
9	....	.....	70.50	118.12	169.62	258.12	338	426
10	....	.....	77	128.13	184	276.18	360	454
11	....	.....	82.88	136.19	195.13	295.69	382	482
12	....	.....	86.37	144.87	209.75	311.94	404	510
13	....	.....	92	155.50	219 37	335.81	426	538
14	....	.....	97.75	163.58	237.50	351.88	448	566
15	....	.....	103.25	170.75	249.06	391.75	470	594

STANDARD SIZES OF WASHERS.

Number in 100 Lbs.

Diam.	Size of Hole.	Thickness Wire Gauge	Size of Bolt.	No. in 100 lbs.	Diam.	Size of Hole.	Thickness Wire Gauge.	Size of Bolt.	No. in 100 lbs.
Inch.	Inch.	No.	Inch.		Inch.	Inch.	No.	Inch.	
⅝	5/16	16	¼	29[illegible]	1¾	13/16	11	¾	1680
¾	⅜	16	5/16	180[illegible]	2	31/32	10	⅞	1140
1	7/16	14	⅜	7600	[illegible]	1⅛	8	1	580
1½	9/16	11	½	3300	[illegible]	[illegible]	8	1⅛	470
1½	⅝	11	9/16	218[illegible]	[illegible]	1[illegible]	7	1¼	360
1½	11/16	11	⅝	2350	3	1½	6	1⅜	360

TABLES OF STANDARD SIZES, BOILER TUBES.

Lap welded American Charcoal Iron Boiler Tubes, standard sizes:

MORRIS, TASKER & CO.

External Diameter.	Internal Diameter.	Thickness.	External Circumference.	Internal Circumference	Length of Pipe per sq. foot inside surface.	Length of Pipe per sq. foot outside surface.	Internal Area.	External Area.	Weight per foot.
Inch	Inch.	Inch.	Inch.	Inch.	Feet.	Feet.	Inch	Inch.	Lbs.
1	0.856	0.072	3.142	2.689	4.460	3 819	0.575	0.785	0.708
1¼	1.106	0 072	3 927	3.474	3 455	3 056	0.960	1.227	0.9
1½	1.334	0.083	4.712	4.101	2.863	2.547	1.396	1 767	1.250
1¾	1.560	0 095	5.498	4.901	2.448	2.183	1.911	2.405	1.665
2	1.804	0.098	6.283	5 667	2 118	1.909	2.556	3.142	1.981
2¼	2.054	0.098	7.069	6.484	1.850	1.698	3 314	3.976	2.238
2½	2.283	0.109	7.854	7.172	1.673	1.528	4.094	4.909	2.755
2¾	2.533	0.109	8.639	7.977	1 508	1.390	5.039	5.940	3.045
3	2.783	0.109	9.425	8.743	1.373	1.273	6.083	7.069	3.333
3¼	3.012	0.119	10.210	9.462	1.268	1.175	7.125	8 296	3.958
3½	3.262	0.119	10.995	10.248	1.171	1.091	8.357	9.621	4.272
3¾	3.512	0.119	11.781	11 033	1.088	1.018	9 687	11.045	4.590
4	3.741	0.130	12.566	11 753	1.023	0.955	10.992	12.566	5.320
4½	4.241	0.130	14.137	13 323	0.901	0.849	14.126	15.904	6.010
5	4.72	0.140	15.708	14.818	0.809	0 764	17 497	19.635	7.226
6	5.699	0.151	18.849	17.904	0.670	0.637	25.509	28 274	9.346
7	6 657	0.172	21.991	20.914	0.574	0.545	34.805	38.484	12.435
8	7.636	0.182	25.132	23.989	0.500	0.478	45.795	50.265	15.109
9	8.615	0.193	28.274	27.055	0.444	0 421	58.291	63.617	18.002
10	9.573	0.214	31.416	30 074	0.399	0 382	71.975	78.540	22.19

WROUGHT IRON WELDED TUBES.

EXTRA STRONG.

Nominal Diameter.	Actual outside Diam	Thickness Extra Strong.	Thickness, Double Extra Strong.	Actual Inside Diameter, Extra Strong.	Actual Inside Diameter, Double Extra Strong
1/8	.405	.100	....	.205	....
1/4	.54	.123	....	.294	..
3/8	.675	.127	....	.421	....
1/2	.84	.149	.298	.542	.244
3/4	1.05	.157	.314	.736	.422
1	1.315	.182	.364	.951	.587
1¼	1.66	.194	.388	1.272	.884
1½	1.9	.203	.406	1.494	1.088
2	2.375	.221	.442	1.933	1.491
2½	2.875	.280	.560	2.315	1.755
3	3.5	.304	.608	2.892	2 284
3½	4	.321	.642	3 358	2 716
4	4.5	.341	.682	3.818	3.136

TABLE OF THE PROPERTIES FOR SATURATED STEAM.

Pressure in lbs. per sq. in. above atmos.	Temperature of steam in deg. Fahr.	Heat above 32° in water at boiling point.	External work in heat units.	Total heat above 32° Fahrenheit in steam.	Internal work of evaporat'n in heat units.	Latent heat of evaporat'n in heat units.	Total internal work above 32° in heat units.	Weight of 1 cubic foot of steam in pounds.	Volume of 1 lb. in cubic feet.
14	90	...	..	1109	...	....	....	...	172 0
13	121	99	62	1118	967	1029	....	.006	172 0
12	138	106	65	1124	943	1018	....	.008	117 5
11	150	118	67	1127	942	1009	....	.011	89 6
10	160	128	67	1130	935	1002	....	.014	72.6
9	168	136	67	1133	925	993	....	.016	61.2
8	175	143	68	1134	923	991	....	.019	52.9
7	181	150	68	1137	918	987	....	.021	46.7
6	187	156	69	1138	913	982	....	.024	41.8
5	192	161	69	1140	909	979	....	.026	37.8
4	196	165	70	1141	906	976	....	.029	34 6
3	201	170	70	1143	903	973	....	.031	31.8
2	205	174	71	1144	899	970	....	.034	29 5
1	209	178	71	1145	896	967	....	.036	27.6
0	212	181	72	1146	893	965	1074	.038	26 3
1	215	184	72	1147	890	962	1074	.041	24 3
2	219	188	72	1148	888	960	1076	.043	23.0
3	222	191	73	1149	887	958	1078	.046	21.8
4	225	194	73	1150	885	956	1079	.048	20.7
5	227	196	73	1151	882	953	1079	.050	19.7
6	230	199	74	1152	879	951	1079	.053	18 8
7	233	202	74	1152	879	950	1079	.055	18.0
8	235	204	74	1153	876	948	1079	.058	17.2
9	237	206	74	1154	873	947	1080	.060	16.6
10	239	208	74	1154	872	945	1080	.062	16.0
11	242	211	75	1155	869	944	1080	.065	15.4
12	244	213	75	1156	867	942	1080	.067	14.9
13	246	215	75	1156	866	941	1081	.070	14 4
14	248	217	75	1157	864	939	1081	.072	13 9
15	250	220	75	1158	863	938	1083	.074	13 4
16	252	222	75	1158	862	937	1083	.076	13 0
17	254	224	76	1159	859	935	1084	.079	12 7
18	256	226	76	1159	858	934	1084	.081	12.3
19	257	227	76	1160	857	933	1084	.083	12.0
20	259	229	76	1160	856	932	1085	.086	11.6
22	262	232	76	1161	853	929	1085	.090	11.0
24	266	236	77	1162	850	927	1086	.095	10.6
26	269	239	77	1163	848	925	1087	.099	10
28	282	272	77	1164	846	923	1088	.104	9 6

TABLE OF THE COMPARATIVE EVAPORATIVE POWER OF DIFFERENT KINDS OF COAL.

Name and description of coal.	Water evaporated per lb. of coal.
The best Welsh	9.493 lbs.
Anthracite	9.14 "
Pittsburg	8.5 "
Average, small, Newcastle	8.07 "
Pennsylvanian	10.45 "
Coke, from gas works	7.9 "
Average, large, Newcastle	7.65 "
Derbyshire	6.772 "
Northumberland	6.6 "
Wallsend Elgin	8.46 "
Slievardagh (Irish Anthracite)	9.85 "
Conception Bay, Chili	5.72 "

CHEMICAL COMPOSITION OF VARIOUS KINDS OF COAL (BRITISH).

Name of elements.	Northumberland.			S'th Wales.		Lancashire.		Scotch.		Welsh.
	Semi-bituminous			Slightly bituminous	Anthracite.	Semi-bituminous.	Bituminous.	Semi-bituminous.	Bituminous.	Anthracite.
	Best house coal much smoke.	Best steam coal much smoke.	Coking.	Best steam coal little smoke.	No smoke.	Home and steam coal.	Gas coal.	Steam coal much smoke.	Boghead Cannel gas coal.	Specific gravity, 1 375.
Carbon	84.3	82.4	86.8	88.3	92.3	82.6	80.1	80.1	63.1	91.44
Hydrogen	5.5	5 4	5	4.7	3	5.9	5.5	6.5	8.9	3.46
Oxygen	6 2	6.4	5.2	.6	2.6	7.4	8.1	8	7	.21
Nitrogen	2.1	1.6	1	1.4	.6	1.8	2.1	1.6	.2	.09
Sulphur	1.2	1.3	.9	1.8	...	.8	1.5	1.4	1	3.39
Ash	.7	2 9	1.1	3.2	1.5	1.5	2.7	2.4	9.8	2.64
Total	100	100	100	100	100	100	100	100	100	100
Coke per ct.	75	35.6	72	84	64	64	60	55	30	92.9

DIFFERENT COLORS OF IRON CAUSED BY HEAT.

C.	Fahr.	Color.
210°	410°	Pale Yellow.
221	430	Dull Yellow.
256	493	Crimson.
261	502	Violet, Purple and dull Blue; between 261° C. to 370° C. it passes to bright Blue, to Sea Green, and then disappears.
370	680	
500	932	Commences to be coated with a light coating of oxide; loses a good deal of its hardness, becomes a good deal more impressible to the hammer and can be twisted with ease.
525	977	Becomes nascent Red.
700	1292	Sombre Red.
800	1472	Nascent Cherry.
900	1657	Cherry.
1000	1832	Bright Cherry.
1100	2012	Dull Orange.
1200	2192	Bright Orange.
1300	2372	White.
1400	2552	Brilliant White, welding-heat.
1500	2732	Dazzling White.
1600	2912	

TABLE OF TOTAL HEAT OF COMBUSTION OF FUEL AND AIR REQUIRED PER LB.

FUEL.	C.	H.	O.	C.'	E.	H.	A.
Charcoal.							
From Wood......	0.93	......	......	0.93	14	13500	11.16
From Peat......	......	......	......	0.83	12	11600	9.6
Coke.							
Coke, good......	0.94	......	......	0.94	14	13620	11.28
" middling..	0.88	......	......	0.88	13.2	12760	.....
" bad.......	0.82	......	......	0.82	12.3	11890	.....
Coal.							
Anthracite.......	0.915	0.035	0.026	1.05	15.75	15225	12.13
Dry Bituminous..	0.90	0.04	0.02	1.06	15.9	15370	12.06
"	0.87	0.054	0.016	1.02	15.4	14860	.....
"	0.80	0.054	0 016	1.02	15.3	14790	.....
"	0.77	0.05	0.06	0.95	14.25	13775	.....
Coking..........	0.88	0.052	0.054	1.075	16.0	15837	11.73
Cannel..........	0.84	0.056	0.08	1.04	15.15	14645	10.58
Dry							
Dry flame........	0.77	0.052	0.15	0.91	13.65	13195	10.32
Lignite..........	0.70	0.05	0.20	0.81	12.15	11745	9.30
Dry Peat........	0.58	0.06	0.31	0.66	10.0	9660	7.68
Dry Wood.......	0.50		......	0.50	7.5	7245	6.00
Oil..............	0.84	0.16	.....	1.52	22 7	21930	15.65
"	0.85	0.15	......	1.49	22.5	21735	15 65

TENSILE STRENGTH OF PLATE AND RIVET IRON.

(By Dr. Fairbairn.)

Description of Iron.	Mean breaking weight in tons per sq in. with fibre.	Mean breaking weight in tons per sq in across fibre.	Ultimate elongation.
Lowmoor iron, (sp. gr. 7.6885).	28.661	23.433	....
Lancashire boiler plate........	21.815	20.096	$\frac{1}{23}$ to $\frac{1}{36}$
Staffordshire iron..............	21.357	......	....
Charcoal bar iron.......	28.402	......	....
Best Best Staffordshire iron....	20.095	......	....
" " " "	22.297	20.745	$\frac{1}{20}$ and $\frac{1}{26}$
" " " "	26.706	24.474	$\frac{1}{15}$ to $\frac{1}{25}$
The best Staffordshire..........	27.357	24.027	$\frac{1}{13}$ and $\frac{1}{22}$
Common "	22.688	25.582	$\frac{1}{20}$ and $\frac{1}{23}$
Staffordshire rivet iron.........	26 801	......	$\frac{1}{4}$
Lowmoor " "	26.646	......	$\frac{1}{4}$
Staffordshire " "	26.563	......	$\frac{1}{4}$
Bar of the same, rolled cold...	37.956	......	$\frac{1}{8}$
Staffordshire bridge iron.......	21.249	19.815	$\frac{1}{25}$ and $\frac{1}{35}$
Yorkshire " "	22.290	19.615	$\frac{1}{25}$ and $\frac{1}{28}$
The very best Yorkshire boiler plate, per sq. in..........	25	......	....
The very best Staffordshire boiler plate...............	20	......	....
The very best American boiler plate......................	31	......	....
Ordinary American boiler plate,	27	......	....
Good average boiler plate.......	20	......	....

PROPORTION OF PARTS OF ENGINES.

Value NHP.—Modern engines work to four to five times NHP.

Grate surface.—Grate surface required per NHP, equal to about three-quarters of a square foot.

Heating surface.—Heating surface equal to about twenty-two square feet.

Coal burnt.—Coal burnt on grate equal to about sixteen pounds per square foot per hour, which is about twelve pounds per hour per NHP; and if engines work up to five times the

NHP, this would be two and-a-half pounds per hour per indicated horse-power.

Weight water.—Weight of water evaporated by each pound of coal equal to from eight to fourteen pounds. In practice ten is good.

Boiler space.—The boiler space about one cubic yard per NHP, of which not more than one-half should be water space, and not less than one-half steam space.

Water per NHP.—Water required to turn into steam per NHP, equal to from one and-a-half to two cubic feet.

Area of tubes.—The sectional area of tubes equal to ten square inches.

Area of bridges.—The area above the bridges equal to fourteen square inches.

Safety valve.—Area of safety valves equal to half square inch for every square foot of grate surface; three-eighths square inch equal to one NHP.

Chimney.—Area of chimney equal to seven square inches.

Piston.—Area of piston for low-pressure condensing engine about twenty-two square inches; and for a high-pressure (non-condensing) engine equal to eleven square inches.

Shaft.—Size of shaft equal to diameter, a little less than one-eighth diameter of low-pressure cylinder.

Crank.—The crank-pin should be one-quarter diameter less than the shaft.

Steam pipe.—The main steam pipe should be about the same diameter as the shaft.

Eduction.—Eduction pipe equal to about one-third the diameter greater than the steam pipe.

Piston rod.—The piston rod about one-tenth the diameter of the low-pressure cylinder.

Pump.—The air pump capacity between one-sixth and one-eighth of that of low-pressure cylinder.

THE METHODS OF FINDING THE MEAN PRESSURE THROUGHOUT THE STROKE WHEN WORKING EXPANSIVELY.

In calculating the work done by the expansion of steam, it is necessary to have a knowledge of Marriotte's law, according to which, is the principle the diminutions take place; and in regard to steam, it may be given in the following words: "If a given weight of steam be made to vary its volume without changing its temperature, the elastic force of the steam will vary in the inverse ratio of the volume it is made to occupy;

that is, if its volume is increased two times, its pressure will be about one-half of what it was at first, and so on."

Four or more different methods exist for determining "the mean pressure throughout the stroke when working expansively."

Simpson's Rule is:

(1) Divide the cylinder into any number of equal parts, (for cut-off at one-half, one-third, one-quarter, one-sixth, etc., twelve parts; if cut off at fifths, ten parts; if at sevenths, fourteen parts; if at eighths, equal to sixteen.)

(2) Divide that part of the stroke through which expansion takes place into any even number of equal parts, and calculate the pressure per square inch upon the piston at each division of the stroke, by Marriotte's law.

(3) Take the sum of the extreme pressures in pounds, per square inch, four times the sum of the even pressure, and twice the sum of the odd pressures: then, this sum multiplied by one-third of the distance between the consecutive points at which the pressures are taken, will give the work done expansively per square inch of the area of the piston in one stroke, and one-third this sum is the total pressure during expansion.

(4) To this add the total pressure before expansion, and divide the sum by the number of parts into which the cylinder is divided; the result is the whole work done during a single stroke. The method by using hyperbolic logarithms (the Naperian curve) is probably the shortest.

Rule:

(1) Divide the whole length of the stroke by the distance through which the piston moves before the steam is cut off, the quotient is the ratio of expansion.

(2) Divide the pressure of the steam in pounds, per square inch, by the ratio of expansion found by (1).

(3) Find the hyperbolic logarithm (see table) of the ratio of expansion, to which add one; the result represents the increase of efficiency due to expansion.

(4) Finally multiply this result (3) by the quotient obtained by (2), which gives the mean pressure throughout the stroke in pounds per square inch.

The next is a short, quick, and easy method, when you have an expansion table with multipliers, but which can be found by adding one to the hyperbolic logarithms of the relative expansions, and then dividing the sums by the relative expansion.

EXPANSION TABLE, OR TABLE OF MULTIPLIERS.

Relative expansion.	Multiplier.	Relative expansion.	Multiplier.	Relative expansion.	Multiplier.	Relative expansion	Multiplier.	Relative expansion.	Multiplier.
1.0	1.00000	2.0	.84657	3.0	.69954	4.0	.59657	5.0	.52189
1.1	0.99574	2.1	.82949	3.1	.68755	4.1	.58805	5.1	.51554
1.2	0.98527	2.2	.81294	3.2	.67598	4.2	.57978	5.2	.50936
1.3	0.97105	2.3	.79692	3.3	.66482	4.3	.57177	5.3	.50334
1.4	0.95462	2.4	.78145	3.4	.65405	4.4	.56400	5.4	.49748
1.5	0.93698	2.5	.76652	3 5	.64365	4.5	.55646	5.5	.49177
1.6	0.91875	2.6	.75212	3.6	.63359	4.6	.54914	5.6	.48621
1.7	0.90037	2.7	.73824	3.7	.62387	4.7	.54203	5.7	.48078
1.8	0.88210	2.8	.72486	3.8	.61447	4.8	.53513	5.8	.47549
1.8	0.86413	2.9	.71197	3.9	.60538	4.9	.52842	5.9	.47033
2.0	0.84657	3 0	.69954	4.0	.59657	5.0	.52189	6.0	.46529

NOTE.—This table is used in calculating the mean pressure throughout the stroke, for example: Suppose cut-off at $\frac{2}{5}$ the stroke, which would be $5 \div 2 = 2.5$ ratio of expansion, and the above table gives for 2.5 the multiplier .76652; this .76652 multiplied by the initial pressure, say forty pounds, give a mean pressure of 30.66080 pounds.

Rule using expansion table :

(1) Divide the length of the stroke by the distance the piston moves before the steam is cut off, the quotient will express the relative expansion it undergoes.

(2) Take from the expansion table of multipliers the multiplier corresponding to this number, and multiply it by the full pressure of steam per square inch on entering the cylinder; the product will be the mean pressure per square inch.

McFarlane Gray gives the following arithmetical rule :

(1) Take eleven ordinates, making as below the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 under one another.

(2) Reduce the ratio of expansion to a decimal, if it is not already so expressed.

(3) Note the first figure of the decimal, and draw a line to mark the "cut-off" below the same figure in the column of ordinates.

(4) Opposite each number (except the first) above the line (see 5) put 1, but for first .05.

(5) Divide the decimal of the ratio of expansion, found as above (2), by each of the other numbers below in succession; but for the last write down half an ordinate found.

(6) Find the sum of all these lines, and multiply it by the given pressure; the result is the mean pressure on the piston throughout the stroke.

STRENGTH OF MATERIALS.

(From Appleton's "Applied Mechanics.")

Tensile strength of cast iron.—The ultimate strength of cast iron ranges from five to seven and-a-half tons per square inch, first meltings; specimen under one inch in thickness.

For thicker castings the strength diminishes. The ultimate strength is increased by repeated meltings to from fifteen to twenty tons per square inch. Factor safety equal to quarter, sixth, eighth.

Wrought iron.—The ultimate tensile strength of rolled bar iron varies from twenty-two and-a-half to thirty tons; rivet iron from twenty-four to twenty-seven; plates from twenty to twenty-three tons, about one ton less crosswise than lengthwise the fibre. The strength is reduced more than one ton by annealing. For a wrought iron round rod of any diameter, the square of the diameter in square inches is about the breaking weight in tons : five tons per square inch of section for factor of safety, and one-fifth of ultimate tensile strength for boilers.

The elastic strength is the strength exhibited by any material without being permanently altered in form, for as a piece of iron is finally broken by being bent backward and forward, so by applying under strain, etc., to any material it will be finally broken with a much less strain than would suffice to break it at once.

The elastic strain of iron, if wrought iron, is from one-third to one-quarter its ultimate strength, tensile, and to this point the material might be proved without any injury, but in proving it is not usual to make the proving pressure more than twice or three times the working pressure, such proof it is considered runs no risk of straining the material while it is adequate to the detection of accidental flaws if such exist. The tenacity or tensile strength, and the resistance to compression or crushing strength of various materials, is given in the following table :

Name cf material.	Tensile strength per square inch of section.	Crushing strength per square inch of section.
Wrought iron bars	60000	27000
" " plates	52000	37000
Cast iron, average	16500	.....
" " toughened	25764	.....
Steel	{ 100000 130000	260000

Table of strength of plate, riveted joints, etc.—Cohesive strength of the plates ; breaking weight in pounds per square inch, 52.486 (mean) ; length of double riveted joint of equal section to the plate through centre of rivets, breaking weight in pounds, 53.635 (mean) ; strength of single riveted joints of equal section of plate through the line of rivets, breaking weight in pounds per square inch, 41.59 (mean).

Steel.—The ultimate tensile strength of rolled steel bars varies from thirty to fifty tons. The average tensile strength may be taken at thirty-five tons. The ultimate strength of steel plates is from twenty-two to thirty-two tons, according to the proportion of constituent carbon.

The strength is the same lengthwise or crosswise ; annealing reduces the tensile strength of steel plates one and-a-half to two tons: nine tons per square inch for factor of safety—mild steel quarter of ultimate tensile strength.

The metals which are found to longest retain heat are brass and copper, next iron, and lastly lead.

SOME USEFUL KNOWLEDGE ABOUT MARINE BOILERS.

One square foot of fire grate consumed twenty pounds (nearly) per hour.

One square foot of fire grate requires thirty square feet of fire place and tube surface.

One square foot of fire grate with the above surface would evaporate 170 pounds of water per hour.

One square foot of flue surface would evaporate 5.66 pounds of water per hour.

One pound of coal would evaporate 8.5 pounds of water.

One horse power of 33,000 pounds, lifted one foot high per minute, required about four and-a-quarter pounds of coal per hour.

MILD STEEL.

(Part of a paper read before the "Iron and Steel Institute, G. B.," by Mr. Richards, F. I. C., A. R. S. M.)

The author has the honor to place before the members of the Iron and Steel Institute the results of a few experiments made in the Kirkcaldy testing machine at the Barrow Hematite Steel Company's Works. Although these experiments are not perhaps of the most practically useful character, they may be of interest as affording an explanation of some phenomena which do not appear to be generally well known or thoroughly understood. For the purpose of experiment, a hammered billet of steel of soft quality, made by the Siemens-Martin process, was rolled to the form of a bar one and seven-eighth inch square. Some drillings were taken from the bar for analysis, and gave the following results:

Carbon	0.192
Silicon	Trace
Sulphur	0.040
Phosphorus	0.048
Copper	0.021
Manganese	0.430
Iron	99.269
	100.000

The bar was divided into eight portions, which were numbered consecutively one to eight. The pieces were turned to the desired form for testing—

Nos. 1 and 4 being finished to the cylindrical form for ordinary tensile test;

Nos. 2, 5 and 8 being grooved transversely to illustrate the effect upon the tensile strength;

No. 3, to ascertain the effect of a long-continued tensile strain approaching the elastic limit;

No. 6, to determine the tenacity of steel which has been previously subjected to a tensile strain approaching the maximum load.

No. 7, to ascertain the tenacity of steel which has been previously submitted to a compressive strain.

The form and dimensions of the specimens were shown by the author by drawings.

Where practicable, the transverse sectional area was made to equal one square inch. The specimens for ordinary tensile test were marked carefully with fine centre-punch marks placed a distance of eight inches apart, this being the length of specimen usually taken for the measurement of elongation by the Admiralty and by Lloyd's surveyors, and it is approximately the same as that used by most continental engineers (two hundred millimetres). The experiments on tension were made in the following manner: The specimen was strained until an extension equal to 1.100 inch was observed; the tension was then noted. The specimen was then pulled until a further small extension was observed; the strain borne was again noted, and so on, these observations being made at frequent intervals during the elongation of the specimen until fracture took place. In some instances the strain and extension were observed forty times during the progress of one test. The diameter of the specimen was also measured at each successive extension. A considerable number of data was thus obtained, sufficient to enable a diagrammatic representation to be made, not only of the extension and varying strain on the specimen, but also of the mechanical work done in breaking it, a quantity which the late Dr. Fairbairn regarded as being of the highest importance in the consideration of the quality of metal best suited to resist a strain analogous to that of impact. Another quantity was also calculated from these data, viz., the real tenacity or cohesive force of the metal. During the elongation of the specimen up to the point when the maximum load is reached, a gradually increasing strain is borne by a gradually diminishing transverse area. The real tenacity or cohesive force of the metal measured on the diminished area is, therefore, manifestly greater than the tensile strain per square inch of the original sectional area. The ultimate cohesive force is determined with some difficulty, and not with the exactitude that may be desired. It is a quantity which is perhaps not of great interest to the practical engineer, but it is impossible to comprehend the *rationale* of the remarkably high strains borne by grooved, drilled, or punched specimens of mild steel without a knowledge of the cohesive force of the metal. The excess of tensile resistance is, however, easy to understand when the cohesive force and the restricted flow of the metal are taken into consideration together.

Referring to the specimen No. 1, no change visible to the naked eye was observed in the length of the specimen on the first application of a moderate tensile strain, even when measured with fine-pointed dividers adjusted to fine centre-punch marks placed eight inches apart. As the specimen did not yield perceptibly, the tension increased rapidly with a few strokes of the pump, and the moveable balance weight of the testing machine was run out quickly from the fulcrum in order to counterpoise the tension on the specimen. Under a strain of nearly fourteen tons per square inch an extension of .01 inch was observed, but there was no sign of further yielding or weakness in the specimen. The steelyard remained floating, and would have continued to do so for an indefinite period, balancing the tension of fourteen tons on the specimen. When the strain was increased to seventeen and-a-half tons, the bar suddenly elongated, and the strain diminished to about fifteen tons, the weight on the steelyard having to be moved back towards the fulcrum, in order to be in equilibrium with the tension. That point at which the specimen suddenly relaxes in tension (in this case at seventeen and-a-half tons) is commonly termed the "elastic limit," although some little extension, amounting to one, two, or three-hundredths of an inch, usually takes place before this point is reached. The microscopic extensions which take place before the so-called "elastic limit" are of considerable interest, and have been very fully described by Professor Kennedy in his admirable paper on the results of experiments on riveted joints made for the Institution of Mechanical Engineers. After the elastic limit was passed, the tensile strain gradually increased, fluctuating slightly, but rising from fifteen tons until the previous highest strain of seventeen and-a-half tons was again reached, the elongation meanwhile being two-tenths of an inch.

No other sudden relaxation of tension was experienced whilst the actual extension was going on up to the point of rupture, but a gradual diminution of the load took place after the maximum strain was borne. A similar although not so large a reduction of strain as that experienced at the elastic limit may be observed, however, at every succeeding stage of the test if the extension be interrupted for a moment. When taking the indications of tension and diameter at each extension of the specimen, it was of course necessary to cease working the pumps so soon as each desired extension was attained. It was noticed that upon doing so the steelyard dropped at once, and the strain diminished about one ton per square inch in the course of a few seconds; but the specimen would sustain this slightly reduced load for a considerable time without further extension. On working the pumps again, the tension rose rapidly to the same load as was on when the pumps were stopped, and then continued to increase slowly as before. The author is of opinion that the resistance of a bar to tension is made up of two quantities, one of which is the pure elastic tension of the metal, and the other the frictional or other resistance which the molecules experience in passing each other to take up new positions. The former is by far the larger quantity. This would explain the reason of the diminution of strain when the process of extension is momentarily stopped; there being then no further extension or motion of the particles, the frictional resistance vanishes, and the strain decreases to the elastic tension of the material. The maximum strain, 28.35 tons per square inch, was borne when the specimen had elongated one and-a-half inches or 18.75 per cent., the sectional area having become reduced to .8168 square inch, a reduction of a little more than eighteen per cent. As the maximum strain is borne by this reduced section, it follows that the cohesive strain at this point is 34.32 tons, or about eighteen per cent. more than the tensile strain per square inch of the original area. The ultimate extension of the specimen, as is well known, varies considerably in different portions of its length, and is, of course, greatest near the fracture. The extension is also irregular at different periods of the test, although the bar is perfectly uniform in diameter. It does not take place simultaneously throughout the length of the bar; for instance, with an extension of one-tenth of an inch the specimen is sometimes drawn in one place, near to one end, the diameter becoming visibly smaller, tending to give one the impression that the bar is weaker there than in any other part. During the next tenth or two-tenths of an inch extension the bar will often draw in the larger part, so that the diameter may again become nearly uniform; afterwards the bar may elongate at the other end of the specimen. Occasionally the sectional area will become reduced in two places at the same time with a larger part intervening, and the fracture often occurs at some point which was the least extended in the early period of the test. This behaviour explains how it happens that the reduced areas recorded in the tables sometimes remain constant during two or three successive extensions. It therefore appears that when one part elongates more than another, it may become so much stronger at the small part under the strain, that it will not extend further until the larger part has drawn in a similar manner. In Table No. 3 there is a column for the position of the smallest diameter during extension in illustration of the foregoing remarks.

When the maximum strain is passed "local extension" takes place, that is, the specimen elongates only in the neighbourhood of the smallest part; the sectional area continues to reduce, but the tensile strain also diminishes as the specimen elongates, diminishing slowly at first, and more rapidly as the point of rupture is approached; in fact, so rapidly that it is often a difficult matter to observe the exact strain borne by the metal immediately before fracture. In the specimen No. 1 the strain diminished during local extension from the maximum 28.35 tons just before breaking, a diminution equal to 11.78 per cent. The sectional area also decreased from .8168 square inch to .5541 square inch, a reduction of 32.16 per cent. As the contraction of area goes on in a greater ratio than the diminution of strain, a peculiar feature in the behaviour of the metal becomes evident, viz., that the tenacity or cohesive force per square inch of reduced area does not diminish after the maximum strain is passed; on the contrary, it increases largely until the bar is fractured. This is shown in a very marked manner in Table No. 1. The cohesive force at the maximum strain is 34.32 tons; at the finish of the test it is 45.21 tons. Some experimentalists have followed the practice of recording in tables of results the quantity termed by them "tensile strength per square inch of contracted area." This quantity is misleading, being obtained by the use of two data that are not coincident. The maximum strain is calculated, not on the area at the moment the maximum strain is reached, but on a subsequent smaller area (the fractured area), which is not capable of bearing the maximum strain. The quantity obtained does not therefore represent the real ultimate tenacity or cohesive force of the metal, except in the case of the hardest and most brittle quality of steels, which usually break at the maximum load. According to this method of calculation it is 51.16 tons in this specimen as against 45.21 tons determined by the author. The extension of this specimen on eight inches was 2.20 inches equal to 27.5 per cent. The contraction of sectional area was 44.59 per cent., and the fractured surface was silky in appearance. The work expended in producing rupture of the specimen is represented on the diagram by the area of the irregular figure ABCDEF, enclosed by the thick line marked "tensile strain per square inch." It is 55.85 inch-tons, or 125,115 inch-pounds, equal to an average of 6.98 inch-tons, or 14,639 inch-pounds for each lineal inch of the specimen.

The formula which Dr. Fairbairn used for calculating the mechanical work is—

$$u = \tfrac{1}{2}\,P,\ l,$$

where u=the mechanical work, $P=\frac{P}{K}$ the strain in pounds reduced to unity of section, P being the tension in pounds, and K the area of the specimen in square inches, and $l,=\frac{l}{L}$ the corresponding elongation reduced to unity of length.

Applying this formula to specimen No. 1, the mechanical work is found to be 8736. This is a very large amount compared with the results obtained by Dr. Fairbairn in his experiments on steel, and even this is far below the real mechanical work 15,639 for unity of length determined by actual experiment. The formula would only be correct if the material of the specimen were so elastic as to permit of the total temporary extension of 2.20 inches without any permanent elongation, in which case the total work done would be represented geometrically by the triangle AGF. As used by Dr. Fairbairn for obtaining a comparative measure of the power of resistance of different bars to impact, this formula would afford reliable although not exact results. Other engineers have used the simple formula u=P, l, which is in excess of, but does not deviate so much from, the exact quantity. The formula deduced from results obtained in testing this specimen by the author should be u=.90P, l,. Another sample of very soft ingot metal made for tin bar purposes, and having a tensile strength of twenty-five tons per square inch, gave results which would agree with the formula u=.90P, l_1. Soft Bessemer steel having a tensile strength of thirty-one tons per square inch gave the formula u=89P, l_1. The mean of the three soft qualities of steel gives .90 as the coefficient; and this was confirmed by the results obtained in testing some Siemens steel plate having a tensile strength of thirty-two tons per square inch. It is curious to observe the change in the appearance of a turned specimen, finished smooth and bright, when tested up to fracture. The external surface loses its beautiful brilliant lustre and acquires a frosted appearance, becoming rough to the touch, and offering some frictional resistance to the callipers used for measuring the diameter. Examined under a magnifying lens, it resembles a number of blunt pin-points projecting outwards from the surface; under the microscope it has a crystalline appearance somewhat like the fracture of grey iron.

Referring back to the author's opinion that the tensile strain is made up of elastic tension and resistance to change of position of molecules, it may be of interest to quote the following experiment: A specimen of tin bar steel having a tensile strength of 25.35 tons per square inch was extended thirty-two per cent. on a length of eight inches, the strain at that moment having diminished to 21.78 tons, and the specimen having contracted 51.6 per cent. of its original sectional area. On stopping the pumps, the strain fell at once to the elastic tension, 20.44 tons, the difference, 1.34 tons, being due to frictional resistance of molecules. Although the specimen was so near the point of rupture, and the breaking load was afterwards found to be only 18.48 tons, yet the specimen sustained the strain of 20.44 tons during two hours without any further extension taking place; in fact, before the specimen could be made to yield, it was found necessary to increase the strain to 21.70 tons, or nearly the same load as was on the specimen when the pumps were stopped. Presuming that the cohesive force of any particular quality of steel remains the same, temperature and other conditions being constant, it is evident that if, by any means, the flow of this mild steel could be altogether prevented, there would be no reduction of area, and the tensile strength would be equal to the cohesive force exerted over the whole of the original area. There would be no elongation of the specimen, but the tensile strength per square inch would be increased from 28.35 tons to 45.21 tons. It is almost impossible to entirely prevent the flow of the metal under tension, but the specimen may be so shaped as to admit of but a small reduction of area, and the tensile strength of such a specimen, compared with a specimen of the ordinary form, is found to be very largely increased.

Specimen No. 2 was prepared to illustrate the truth of this proposition. The central cylindrical portion was turned to a diameter of one and three-quarter inch for a length of eight inches, and a groove of 3.32 inch in width was turned with a round-nosed tool at the middle of the bar to a depth sufficient to leave the diameter at the bottom of the groove one and one-eighth inch or one square inch in area. This specimen bore a strain of 26.50 tons at .01 inch extension. No sudden relaxation of strain corresponding with the elastic limit was observed, and the strain gradually increased, as shown in the diagram, at each extension of $\frac{1}{100}$ inch up to 40.48 tons per square inch, when the specimen broke suddenly, the fractured surface being of a dark crystalline appearance at the centre and silky near the circumference. The shortness of the extended portion precluded the observation by ordinary dividers of a "breaking-down" period when the elastic limit was reached, and for the same reason no gradual diminution of strain was observed, even if it took place after the maximum strain was reached. In dealing with grooved specimens of the softest class of mild steel, it is, however, possible to observe both the elastic limit and the diminution of load after the maximum strain. This may be done by extending the specimen at an extremely slow rate, and by the aid of a suitable apparatus for measuring very minute extensions. The extension at the moment of fracture was 0.09 inch, equal to one hundred per cent. The reduction of area measured after fracture was 13.45 per cent. only, against 44.59 per cent. in the ordinary tensile test specimen No. 1. The strain was so great as to cause a small contraction (2.82 per cent.) of the sectional area of the large portion of the specimen; and there can be no doubt that the extraordinary high percentage of extension, accompanied by so small a reduction of sectional area in the grooved part, is to be accounted for by the metal being drawn from the large part on either side into the constricted portion.

The cause of the difference in flow and the increased tenacity of the grooved specimen may be explained by the following theory: Let a filament or single chain of molecules or atoms of ductile metal be imagined to be submitted to tensile test, and let the length of the chain be eight inches. Under tension each molecule would become separated from its neighbor so far as their cohesive attraction would permit. On releasing the strain the molecules would return to their original positions, and no permanent extension of the chain would have taken place, the chain being perfectly elastic. The greatest distance which one molecule could be separated from its neighbor would be an infinitely small quantity, and the total of the numerous extensions of the intermolecular spaces would probably not exceed 0.03 inch on the full length of the chain (eight inches). This extension would represent the real limit of elasticity, beyond which rupture would ensue. The strain borne under this greatest temporary extension would be the elastic limit, the cohesive force, and the tensile strength. If the extension were pushed beyond this limit of 0.03 inch or thereabouts on eight inches, the chain of molecules would break, but each broken portion of the chain would show no indication of permanent set. Now, a cylindrical test-bar of mild steel may be regarded as a vast aggregate of chains of molecules, each link having the peculiar faculty, under high tension, of leaving its own chain and taking up a position between the two nearest links of an adjoining chain of molecules. The chains of molecules may thus become permanently elongated by the addition of new links, but they are at the same time reduced in number. The permanent elongation of a specimen is an indication that such a flow of the molecules has occurred. The direction of the flow of the molecules is from the exterior to the interior, and the specimen diminishes in diameter. Each chain in the aggregate may be supposed to be capable of bearing the same strain as if tested alone, or as if it had not become elongated by the addition of neighboring molecules; but as the chains are fewer in number, the total strain carried by the whole mass prior to rupture is less than if the flow of the links or molecules could have been prevented. For a simile, it is plain that 1000 feet of ordinary iron chain, having a tensile strength of one ton, may be divided into a hundred equal lengths of ten feet, which, by their combined tension, may be made to support a load of one hundred tons; but if the chain be divided into fifty parts, each twenty feet long, the united strength of the fifty parts is only fifty tons. In the case of a test specimen of ductile material, each molecule, however, is not only a link of a chain in a longitudinal direction, but it may also be regarded as a constituent link of molecular chains in all directions, including, of course, the transverse: this is evident from the equal tenacity of specimens of steel plate cut from the plate either longitudinally, transversely, or in any other direction. In an ordinary eight-inch cylindrical specimen, the end links of the transverse molecular chains come to the surface and are free. They, therefore, offer no tensile resistance to the flow of the molecules in a transverse direction. In a grooved specimen, the transverse molecular chains are not free, but are united to the ring of external metal; and if this ring be of sufficient strength to resist the transverse tension, the reduction of area will be so slight that the tensile strength per square inch of the specimen will approximate to the cohesive force.

Although a high strain is required to break a grooved specimen, yet the extension before rupture is so small (0.09 inch), owing to the shortness of the extended part, that the mechanical work done in breaking the bar is trifling. The units of work done in breaking the specimen are only 2.79 inch-tons, or about one-twentieth part of the energy consumed in breaking the eight-inch cylindrical specimen. If tension were applied to these specimens by means of a very heavy weight moving at low velocity, the relative energy of the blow required to break the specimens would be as one to twenty. It must not be supposed that the author would advocate, under any circumstances, the grooving of a bar of metal with a view to gain strength. A ductile or a hard cylindrical test specimen having a transverse groove in it must always break in the grooved part, provided the metal be in a normal condition—that is, of homogenious quality and free from undue internal strain. General experience would lead one to observe that large and abrupt variations in the dimensions of pieces of machinery, or portions of structures subject to blows or vibrations, should be avoided. The contour of all forgings, etc., varying in dimensions in different parts should be rounded and not angular. This is a maxim that cannot be too often impressed upon those who are engaged in constructive work in metals.

A SHORT HISTORY OF THE STEAM ENGINE.

The early history of steam is wrapped in obscurity, being used by the priests for to create the marvelous in the idolatrous religions and altar rites.

Hero, supposed to have existed about 225 to 150 B. C., is the first to mention the use of steam, although it appears to have been incidentally referred to by such ancient authors as Homer and Plato.

Hero's inventions consisted of a display of his knowledge of the properties of steam, air and water, and among the most useful are a fire engine, pump, water clock and steam engine, all of a crude and primitive style. Hero may be credited with the invention of the first rotaty engine, capable of giving motion to machinery. Steam was generated in a hollow cylindrical vessel, with a tube passing out of top, on the end of which was freely suspended a globe with two arms, with holes on one side of an arm; the steam in issuing out against the air produced the rotation of the globe, and by a pulley on centre part of globe, motion could be communicated to machinery.

Anthemus, Gubert and Alberti made use of water and heat for frivolous purposes.

In Spain, LeGaray put a boiler on board of a vessel and propelled it by paddle-wheels; the vessel was about 200 tons, and made three miles per hour, and was probably driven by one of Hero's style of engines.

The force of steam, and the rapid vacuum produced by its condensation, are both ably treated by Cardan, who also invented the smoke-jack as still used to illustrate the power of hot air; he lived about the year 1557.

Mathusius, in 1571, refers to the use of steam, and seven years later a rotary engine was used to turn a roasting-spit, a great and clean improvement on the dog.

Ramilli, Bressen and Platti's works show quite a knowledge of steam and its uses, and also the names of Porta Ruanet, DeCaus and Ramsay.

In 1629, Branca gives a description of a rotary engine, the top of the boiler was like the head of a man, in form, with a pipe in his mouth, blowing a jet of steam against the arms of a wheel to cause it to rotate on its axis, and by the pinion give motion to a machine.

The Marquis of Worcester, about 1660, made use of steam to work engines for pumping water.

Hantefeulle tried to work engines by gunpowder and alcoholic vapor. To Isaac Newton many of the later inventors were indebted for the correct theory of steam.

Papin flourished about 1680–1707, he was the inventor of the steam digester; and to regulate the force of the steam in the digester he invented and employed the steelyard safety valve.

In 1687, Papin constructed an atmospheric engine for raising water, to drive a wheel which also worked an air pump for producing a vacuum in mine pipes; and to render the action continuous two cylinders were joined together by a two way cock, which alternately opened each cylinder with the air pump and the atmosphere.

Papin soon learned that a good vacuum was a requisite thing, but abandoned his own invention to perfect Savary's, for the Elector of Saxony; this was called the Elector's engine.

Papin also used two or more cylinders for his steam vessels; he was the first to systematically try to save fuel by improved boiler, and in which he succeeded.

In 1699, Daguet propelled a boat at Havre by steam-revolving oars.

Great energy was displayed by Savary in improving the steam engine; his engine was the same as those formerly used, with the exception of pouring cold water over cylinder, to produce a rapid vacuum each stroke. He improved steam admission valve and construction of his boilers. It is of Savary that it is related that he accidentally discovered the force and condensation of steam, from a wine flask not quite empty being thrown on a fire and producing steam, when he took it off the fire and immersed its mouth below cold water, which condensed the steam and filled the flask by atmospheric pressure.

Newcomen's atmospheric engine dates about 1720. Newcomen was a blacksmith, he introduced the beam or balance lever. At first Newcomen adopted Savary's plan, but a faulty cylinder having admitted water internally, the condensation was more rapid, with increased effect from the engine. Since that discovery internal injections has generally, but not always, been adopted. The various cocks and valves were all opened by hand until a young lad, attending one of the engines, ingeniously connected them with the beam by strings and catches, so as to open them with much regularity; this was the means of introducing the self-acting hand gear.

Desaguleir improved Savary's engine, and Brighton improved the hand gear, etc. Leopold, in 1720, recalled attention to the high-pressure steam engine.

Dicken and Allen, about 1725, proposed an engine to raise water, move mills and ships. Allen propelled by a jet of water forced through the stern of the vessel below the surface of the water, same as Fitch in 1788.

Allen proposed a fire box boiler, with spiral flue through the water and a bellow blast to urge the sluggish vapour through the tubes.

Gensame, in 1730, by the gravity of water and impulse of a falling weight, made the steam valve and injection cock self-acting.

In 1736, Jonathan Hull made an effort to apply a single acting steam engine to propel ships. This plan was to produce rotation by rachet wheels aided by a weight, whereby to move a central paddle-wheel in deep water, or two poles alternately thrust against the ground by a double crank axle in shallow water.

A few years later Payne investigated the density of steam, and Blake discovered the proportion of cylinders. Fitzgerald was the first to make use of the fly-wheel, 1757.

To Dr. Black, 1762, we owe the doctrine of latent heat. Blakey introduced a kind of tubular boiler in 1756. Smeaton's experimental engine of one horse-power evaporated six and-a-quarter pounds of water by one pound of coal, and required eleven times more water for condensing than generating the steam; its best effect was produced with a pressure of eight pounds above the atmosphere. He also determined the relative steaming value of different coals.

The action of the engine was the same as Newcomen's, air being the principal motive power. In some of his boilers, Smeaton inclosed the fire and supplied the fuel by a feeding tube.

Cagnot, a French engineer, constructed a steam locomotive in 1771, the piston worked downwards, as afterwards adopted in Cornwall, England, by Bull, to evade Watt's patent, and now in pendulous engines by various makers.

The distinguished and world-renowned mechanical engineer, Watt, was born at Greenock in 1730, and died at Birmingham, England, after a most successful and busy life, aged eighty-nine. At Glasgow, in 1759, he received a suggestion from his friend, Dr. Robison, as to the application of steam to propel wheeled carriages, but for a time all his energies were, with a success that astonished the world, rendered to apply steam to clearing mines of water.

Watt so vastly improved the steam engine that he has stamped his name on it, as if he had been the original inventor.

After several trials on condensing steam in another vessel connected with the cylinder, in 1769, Watt successfully added a separate condenser to Newcomen's engine, and the double acting cylinder was added and a conical valve was used to open and close the steam passages, worked from the beam; and in 1784 he patented his beautiful parallel motion, an arrangement by levers to correct the vertical motion of the piston rod; and to guard against irregular generation of steam affecting the motion of the engine, Watt introduced the throttle valve, worked by the governor and combined with the fly-wheel. These admirable inventions made the steam engine so regular in its working as to make it very useful; and in 1780 Pickard applied the crank and connecting rod to the steam engine. Watt, however, complained that the crank was part of his design, unfairly obtained through one of his workmen, but he invented another devise for the purpose, the sun and planet rotary, for use during the existence of Pickard's patent.

After the first successful application of the steam engines to machinery, more graceful forms and superior finish were given to parts, etc., by Watt, until the steam engine became a beautiful as well as useful machine. With such able rivals as Smeaton, Hornblower, Trenthick, Bramah, Wasbraugh, and others, often disputing the validity of his patents or seeking to evade them, Watt's ultimate success has imperishably associated him with the steam engine.

About this time Compte Auxiem and Piene, of France, proposed a screw propellor for ships which gave a backward or forward motion by reversing the revolution of screw.

In 1776, Wasbraugh, of Bristol, a rival of Watt's, proposed to propel ships, raise water or drive mills by steam engines with the screw.

The following names of improvers, etc., of Watt's engine, with a short notice of each, may be interesting:

HORNBLOWER, 1781. Patented a judicious arrangement of an additional cylinder to employ the expansive forces of steam after it had done its duty in a small cylinder, on the plan of two cylinders for the expansive action of steam. Hornblower's rotary engine had two moveable pistons, alternately moving round the steam cylinder and acting as abutment valves to each other; a tappet valve in each piston was opened as it came in contact with the abutment, one of which was set at liberty and the other arrested by sliding levers behind it, and so on, alternately.

BRAMAH, 1783–1797. He was another rival of Watt. He improved construction of two way cock of Papin by making it turn quite round to equalize the wear. He is chiefly remembered for his hydraulic press and his celebrated lock.

FITCH, 1783–1788. An American. He moved a boat by paddles on the Delaware, 1783, and on a trial trip to Philadelphia, in 1789, a speed of eight miles an hour was made.

OLIVER EVANS, 1784–1804. He introduced the cylindrical boiler, with an internal flue and leading back below the boiler to the chimney. To further economize fuel the exhaust steam was made to pass specially through a pipe in a cistern of water to heat it for the boiler. In 1804, he showed the practical use of his engines by fitting one of them on a rough wagon and afterwards in a boat.

MURDOCK, 1784–1789. This able assistant of Watt serviced him about twenty years, earning a name intimately associated with Watt's steam engine in Cornwall, where he was much respected. The eccentric motion and long D slide valve were his inventions.

TRENTHICK, 1790–1816. He, like Evans, preferred high pressure steam; his name is connected mostly with the perfecting of the locomotive.

SYMINGTON, 1785-1804. He constructed a crude style of steamer of the modern stern or centre wheel steamboat.

CARTWRIGHT, 1797. He patented an ingenious parallel motion, metallic piston, an air pump, and an external condenser; power looms and carriages without horses, etc.

FULTON, 1793–1807. This able and persevering man had long been engaged in promoting various plans of steam navigation. He visited Scotland, acquainted himself with Symington's neglected steamboat, returned to America and successfully introduced it on the Hudson. To Fulton is due the credit of going to Great Britain and carrying into practice with the best results to mankind a British combination neglected by that nation. Fulton's first steamboat, the "Clermont," built in 1807, was 130 feet long, 16½ feet wide, 7 feet deep, and 160 tons burden; worked by one of Watt's double-acting engines.

American river steamboats are now celebrated for their size, superior accommodations, number, low fares and speed, over those of any other nation. On the Hudson, for instance, where steam navigation for hire was just introduced, besides many smaller vessels averaging 200 feet long, there are upward of a dozen floating steam palaces averaging 325 feet in length, and over a 1,000 tons burden each, and many of them travel twenty miles an hour.

BELL, 1800–1812. Built two small steamboats for outside service, that averaged about six miles an hour.

STEVENS, 1804. With a Watt's engine of only four and-a-half inch cylinder and nine inches stroke, supplied with steam from a boiler consisting of eighty-one horizontal copper tubes one inch in diameter and two feet long, Stevens of Hoboken, N. J., U. S. A., propelled a steamer four miles an hour by a screw, on the principle of the smoke-jack vanes. The tubular boiler deserves notice from the number and position of the tubes, being similar to the modern locomotive boiler.

ERICSSON, 1853. In England he designed a rotary engine steamboat, with great velocity in the water, but a very large consumption of fuel.

An American captain, named Stockton, built a larger boat with a Ericsson propeller at Liverpool, and sent it to America where it plied with great success on the Delaware.

From the earliest accounts to the present time the history of the steam engine covers a period of over 2,000 years; the rotary has been left in the rear by the reciprocatory engine.

The first modern engine was the work of a Scottish mechanic, Watt; to Cuynot and Trenthick we owe the steam locomotive; the first modern type of steamboat was built by Symington, a Scottish mechanic; and the first regular river steamer by an American, Fulton; and the first ocean steamer to the Scottish engineer, Bell.

For a more extended account of their lives and work, which will be found very interesting and instructive reading, Prof. Thurston's work, "The Growth of the Steam Engine," and Clark's "Steam and the Steam Engine," will be found to contain all that is necessary, coupled with the biographies of the principal names in the foregoing account.

PART II.

INAUGURAL ADDRESS.

(Delivered by the Author at the opening of the Engineers' School, St. John, N. B.)

I wish to address a few words to you this evening, in the first place as to the reason why we are gathered here to-night, and secondly, on technical and theoretical education and engineering in general.

I think you all understand that our work, first, is to get an insight into the calculations and theory of engineering, to which we will proceed to work, prepared in this manner: everyone will have what may be called a common-place book, which will be simply a blank-book, for entering anything of interest, as notes from the lectures, rules, data, and examples of same, with tables and resulting facts evolved therefrom, so you may always have it as a help to memory.

The first subject treated in our course will be arithmetic, and more particularly decimals and the roots, such as square and cube, because these rules occur so often in all arithmetical work pertaining to engineering, that at least an elementary knowledge is necessary; and, hereafter, a few words on formula and rules, then we will pass on to the calculations and questions required by law for a Canadian engineer to pass for a Chief Engineer's Parchment Certificate, which involves all the work necessary to pass any grade; of course, as at present, that is the highest grade, there being no "Special Engineer" grade as in England; the minor grades will be pointed out and specified according to their class and examination requisite.

After a thorough grounding has been received in the examination calculations, and questions have been obtained, then calculations of general interest to engineers will be taken up; and after you have formed an acquaintance with all these I will then commence, by a series of articles and diagrams, to explain to you theoretically the working of the indicator, slide-valve, screw eccentric, paddle-wheel, etc., which will require a knowledge of mathematics beyond arithmetic, and which will, therefore, have to be dealt with; by a number of lectures I hope to be able to make you all conversant with the properties of materials of construction, coal, combustion and steam, and the elements related to or connected with them.

I may say here, once for all, that a great deal depends on yourselves and your interest and work, as to the permanent good achieved by this winter's school, so I advise you to take note of everything, and set down in black and white in notes and figures as much as you can, and study during your leisure moments those subjects, for education combined with practice is that attention is concentrated now more upon the principle of phenomena than the phenomena themselves.

Formerly the hope of invention lay in genius, now more in the understanding of theory with practice, and being conversant with all the laws pertaining thereto.

From what was once called Professor Treadwell's pardonable vagaries, has now in practice sprung the single track railroad and the spinning of cordage yarn; also the best and latest cannon; therefore, you will see the result of the steady application of a sober, laborious scholar, adducing practical plans from theory, formulated by the established principles of physics, mathematics, and kindred sciences.

One of the most striking illustrations of the change in common things, which has been brought about by knowledge, is the rail of the railroad. Formerly it was an iron edge rail supported by chains, and having more iron in the base than the head. Clumsy as the rail was, it was claimed to be the only form for the purpose; now the rail is of steel with well defined tread web and base, the principal weight of metal is where it is most needed, and every line subjected to the finest physical tests.

In fact, the short and long of it is: now is the age of engineering, as the past was one of invention and the study and mastery of the principles of mathematics and physical science; the ability to express those things in drawings and clear descriptions, and to apply to the solution of practical problems in machinery and handicraft, are the essential qualities to be combined with practical experience in a good mechanical engineer.

Men are born just as ignorant as they ever were, and the same steps from ignorance to even the elements of knowledge must be taken at some time by all who wish to become intelligent men; but all it really requires is the beginning, and then stick to it and half the battle is over.

A man must understand intelligently the thing he is working at, or he cannot obtain the best results: we all have leisure enough to acquire many things.

The cultivation of reading and keeping notes of the same is very productive of good results; for instances, the works of Edwards, Rankine, Wilson, Haswell, Read, Ansley, Roper, Bourne, Clark, etc., must, of course, produce a lasting impression of facts, adduced from practice and theory combined, on the mind of the engineer that understandingly reads them.

The United States naval engineer, King, says in his book: "Having had many difficulties to surmount in our earliest studies of the steam engine, we were led to the course of keeping a steam journal, in which we noted from time to time, as we progressed, whatever we thought important and was made clear to our mind; and this course we would recommend, for however well it may be to study books containing other men's thoughts, when we write we are led to the habit of thinking for ourselves, which is of the highest importance, and by keeping a journal we have also the very great advantage of having always at our command, in a condensed form, those things which are the most important."

Much has been said about theoretical *versus* practical education, and the working at hard work as well as hard facts, and though no one will deny the great advantage of how to do a thing from practical knowledge and skill, still no one must run away with the idea that theoretical exposition of many things are not practical, for much of such conclusions have been drawn from the practical experience of many heads and hands; for instance, see what Professor Rankine says in the introduction to his "Manual of the Steam Engine and Prime Mover": "In the history of mechanical art two modes of progress may be distinguished—the empirical and the scientific. Not the practical and the theoretic, for that distinction is fallacious; all real progress in mechanical art, whether theoretical or not, must be practical. The true distinction is this: that the empirical mode of progress is purely and simply practical; the scientific mode of progress is at once practical and theoretic.

"Empirical progress is that which has been going on slowly and continually from the earliest times to the present day, by means of gradual amelioration in materials and workmanship, of small successive augmentations of the size of structures and power of machines, and of the exercise of individual ingenuity in matters of detail. The mode of progress, though essential to the perfecting of mechanical art in its details, is confined to making small alterations on existing examples, and is consequently limited in the range of its effects.

"Scientific progress in the mechanical arts takes place, not continuously, but at intervals, often distant, and by great efforts. When the results of experience and observation on the properties of the materials which are used, and on the actions which take place in a class of machines, have been reduced to a science, then the improvement of such machines is no longer confined to amendments or enlargements in detail of previously existing examples; but from the principles of science practical rules are deduced, showing not only how to bring the machine to the condition of greatest efficiency, consistent with the available materials and workmanship, but also how to adapt it to any combination of circumstances, how different soever from those which have previously occurred. When a great advance has thus been made by scientific progress, empirical progress again comes into play to perfect the results in their detail."

Mechanics is that branch of natural philosophy which treats of force and application in machines, in which motion, resistance and velocity play a very active part; this you will find a very interesting study, embracing gravity and the centre of gravity, the mechanical powers, hydrostatic, etc., and giving you such knowledge as to even trifling and common things as to guard you from the mistake of the man who tried to raise himself over a fence by pulling at his boot straps, or the no less ingenious one who rigged a huge bellows in the stern of his sailboat so he might always command a fair wind, for you will know that action and re-action are equal.

Friction you will find also treated, and although it may be the cause of loss of power, still it is not without its use, for even nails would be useless, as they would draw out, but for friction; the band, cog, crown and bevel wheels of machinery may be also mentioned in connection with friction. The general law of friction may be said to be: "The friction which a given pair of solid bodies, with their surfaces in a given condition, are capable of exerting, is simply proportional to the force with which they are pressed together." The power of an engine is the energy exerted, as the effect is the useful work performed by it in a given time: the horse-power of an engine is 550 foot-pounds per second, or 33,000 per minute, or 1,980,000 per hour, and the effect is equal to the power, multiplied by the efficiency.

The next subject to engage our attention to-night will be the familiar one of steam, and the following account, drawn from many sources, may prove interesting to you:

Steam is a thin, elastic, invisible fluid, generated by the application of heat to water; as the mean pressure of the atmosphere at 60° is 14.7 pounds (or in other words, steam airsing from water at its boiling point is equal to the pressure of the atmosphere, which is 14.72322 pounds per square inch,) which is equivalent to a pressure of a column of mercury 29.9212 inches in height. Under this pressure fresh water boils at 212° F. The 212° is not the total number of degrees of heat in the steam, but simply that which is indicated by the thermometer, and which is termed sensible heat; for we all know that to raise water from the freezing to the boiling point requires a certain time and a certain amount of fuel; and we know further that when the water commences to boil it does not all evaporate at once, but that the evaporation goes on gradually all the time, hence the fuel required to evaporate it is much greater than that required to raise it from the freezing to the boiling point; this extra heat must have gone off somewhere and must be in the steam, but as it is termed latent heat. When the steam is reconverted into water, the latent heat becomes again sensible, which is evident by the large amount of water required to condense a small amount in the shape of steam.

The heat contained in vapor, above that necessary for producing the temperature, is what is meant by the latent heat of steam.

It requires as much heat to raise one pound of boiling water at 212° into steam as is required to raise five and-a-half pounds of water from the freezing point (32° F.) to the boiling point (212° F.)

In steam at 212° F. there are 212° of sensible heat and about 1000° of latent heat, being 1212°; as one increases the other decreases. A cubic inch of water evaporated under the ordinary atmospheric pressure is converted into, say nearly one cubic foot, and exerts a mechanical force equal to the raising of 2120.14 pounds one foot high—27.2222 cubic feet of steam, at the pressure of the atmosphere, weighs one pound.

The velocity of steam, when flowing into a vacuum, is about 1550 feet per second when at an expansion power equal to the atmosphere; when at ten atmospheres 1780 feet; when flowing into air under the same pressure 680 feet, and increases to 1600 feet for twenty atmospheres.

Water contains a certain amount of air, and when it is converted into steam this air is mixed with it, and when the steam is condensed it is left in a gaseous state. If means were not taken to remove this air or gaseous matter from the condenser of a steam engine it would fill it and the cylinder, and obstruct their operations; but, notwithstanding the ordinary means of removing it (by air pump) a certain quantity of it always remains in the condenser; twenty volumes of water absorbs one volume of air.

Having taken a glimpse of some of the subjects I intend to treat in full in the future lectures and lessons, I may recommend to your consideration a complete encyclopædia of elementary, advanced and technical education, called the "Popular Educator," issued in monthly parts, or two bound volumes, by Cassell & Company, London and New York; a work intended for those who wish to become self-educated, and therefore its special fitness for engineers and mechanics, who will find their vocation in life has not been forgotten in the multitudes of interesting things in its pages; and when they master these they may add the two additional volumes of the "Technical Educator," having then a complete library for study and reference that will not cost over a week's wages.

The following extract from an article on heat is from its pages, minus the illustrations:

"A simple experiment, which may be easily tried, will enable us to determine exactly the quantity of heat which becomes latent when ice is converted into water, or water into steam.

"Let a uniform source of heat be procured, and let a pound of water be placed over it, so as to ascertain exactly the amount which its temperature rises in a given time. We will assume that it is found to rise 10° in one minute. Now remove this vessel and substitute one containing a pound of ice at a temperature below 32° F, and having a thermometer placed in it. The temperature will rise 32°, and will remain at that point a trifle over fourteen minutes, at the end of which time the ice will all be melted. Now in this time the amount of heat received is evidently sufficient to raise a pound of water a little over $14 \times 10°$; or say 142°, yet the water is still only 32°. This amount of heat, then, has been rendered latent. Let the vessel still remain exposed to the heat, and in eighteen minutes it will have attained the boiling point, for $18 \times 10° + 32° = 212°$. Now, without disturbing anything, wait and see how long elapses before it is entirely boiled away;

it will be found to be about ninety-five minutes, or nearly five and-a-half times as long as it took to rise from 32° to 212°, and yet the temperature of the steam has at no time exceeded 212°. All this amount of heat, then, has been rendered latent, and is, viz., $5\frac{1}{2}\times180°$=or, nearly 1000°.

"We can, however, easily recover it by the arrangement shown in fig. 13. The steam which is given off is conducted by glass tubing into a vessel, A, filled with a given weight, say five and-a-half pounds of water at 32°. After some time the water in A will boil, and then it will be found that the amount of water in it is just six and-a-half pounds, showing that one pound of steam has been condensed, and the latent heat (viz., $5\frac{1}{2}\times180°$, or nearly 1000°) has been sufficient to raise five and-a-half pounds of water 180°.

"It is this large amount of latent heat in steam that renders it so useful as a heating agent, for it must be remembered that heat cannot be destroyed or annihilated, but is rendered sensible again when the steam becomes condensed.

"The great degree of heat to which the human body may be exposed without danger has often excited much attention. Meat and eggs have been cooked by being placed in a heated room in which men have remained all the time, and suffered no evil effects. The temperature of their bodies, even, has scarcely been at all increased by the high temperature around them. The reason of this is now, however, clear; the heat, instead of being employed in raising the temperature of the blood, is expended in preparing the perspiration and converting it into vapour, and in this way the whole of it is expended. The perspiration acts, in fact, as a natural safety-valve to regulate the temperature.

"The addition of salts to water lowers its freezing point; hence, sea-water does not freeze till 4° or 5° below 32°; when, however, it sinks to this the salts are left in the water around and the ice is perfectly pure. If all the air be driven out of water by boiling, and it is then allowed to cool without being disturbed, and is exposed to a low temperature, it will not freeze till several degrees below 32°; but as soon as any ice forms, the rest of the water will at once rise to that point, clearly showing that the latent heat of water is given off as it freezes. This fact clearly explains why a coat of ice forms so slowly. Were it not for this provision, as soon as any mass of water had sunk to the temperature of 32° it would become a mass of ice; but now every particle as it freezes gives out its latent heat, and thus raises the temperature of the rest.

"In the same way, were it not for the latent heat of steam, the moment when water attained the boiling point would be a very dangerous one, for it would then be immediately converted into steam with an explosive force greater than that of gunpowder, since a cubic inch of water occupies nearly a cubic foot when converted into steam.

"Dissolving any substances in a liquid always lowers the temperature. This may easily be seen by throwing some soluble salt into water, and carefully observing the effect produced on a thermometer placed in it. This absorption of heat during liquefaction is turned to account in the preparation of freezing mixtures for the production of artificial cold. In these, two or more substances, which have a chemical affinity for each other, and of which one at least is a solid, are mixed together, and during the solution a considerable amount of heat is rendered latent.

"Many different mixtures have been used, one or two of which we give here:

"A mixture of about two parts of snow or pounded ice to one of salt will reduce the temperature to 0° F. (zero.)

"This point, in fact, was chosen by Fahrenheit, as the zero of his scale, as he believed it was the lowest temperature attainable.

"The mixture rapidly liquefies, and if a small vessel of water be placed in it, the water will be speedily frozen. A mixture of six parts of sulphate of soda, five of nitrate of ammonia, and four of dilute nitric acid, will cause a still greater reduction of temperature.

"As we have seen, water, on attaining the temperature of 212°, enters into a state of ebullition; a large number of bubbles of steam are produced at the part of the vessel which is exposed to the source of heat; these rise through the liquid, violently agitating it as they burst. The point at which this ebullition commences is that at which the tension of the steam becomes sufficient to overcome the pressure of the atmosphere; and hence, if this pressure be increased, the boiling point will be raised.

"Thus, though the boiling point of water is said to be 212°, this is only true when the barometer stands at thirty inches; when it is lower than this, water boils at a lower temperature.

"In an open vessel the temperature of a liquid can never be raised above its boiling point, as all the surplus heat received is employed in evaporating the water.

"If, however, a closed vessel be employed, the pressure may be increased, and a much higher temperature attained.

"The apparatus usually employed for this purpose is known as Papin's digester, and is represented in Fig. 14. It consists of a strong iron vessel, D, the lid of which is fixed on tightly by means of a screw. B. A safety-valve, S is also provided, so as to allow of the escape of the vapour when its elastic force becomes too great. In this way a temperature greatly exceeding 212° may be attained, and many substances are thus dissolved which are otherwise insoluble.

"The fact that water boils at a lower temperature, if the pressure on it be diminished, may be easily proved experimentally. Pour some water into a flask, and place it over a spirit lamp until it boils; when the steam is issuing freely remove the lamp, and cork the flask tightly. After a few minutes pour a stream of cold water on the outside and ebullition will immediately re-commence. The steam had expelled the air, the upper part of the flask being filled with watery vapour of the same tension. The cold, however, condensed this, and thus a partial vacuum was produced and the pressure diminished, in consequence of which the water began to boil.

"When water is converted into vapour, much heat is rendered latent. In this way the porous water bottles, (frequently used in hot weather), act. A portion of their contents slowly percolates the unglazed ware and evaporates from the surface, absorbing from the vessel the heat required to convert it into vapour.

"If ether, or any volatile liquor be dropped on the hand, a sensation of cold will be at once produced, and this will be felt more distinctly if the hand be waved about or a current of air driven over it, so as to accelerate the evaporation. The same thing occurs to a less extent with water. An important application of this fact is now made in surgery. A stream of finely-divided ether spray is blown upon any part of the body and by its rapid evaporation produces cold enough to freeze the flesh, and thus render it insensible to the cut of the surgeon's knife. In minor operations this plan of producing local insensibility is frequently adopted.

"By the arrangement shown in Fig. 15, water may be frozen by its own evaporation. A shallow vessel, filled with strong sulphuric acid, is placed under the receiver of an air-pump, and over it is supported a thin metal vessel, A, containing water. As soon as the air is exhausted, vapour begins to rise, and the vessel would speedily become charged with it, did not the acid absorb it as fast as formed. Each fresh portion of vapour lowers the temperature, and this continued abstraction of heat soon turns the water into a lump of ice.

"Some vapour is given off at temperatures far below the boiling point. The air, in fact, is always more or less charged with it. There is, however, a certain limit to the amount it can contain at any temperature, and if, when it is fully charged, the temperature fall, a portion of the vapour is precipitated in the form of rain. The point at which this vapour in the air begins to be precipitated is called the "dew point," and the temperature of this depends upon the amount of vapour present. When on a clear night any objects become cooled below this point, the air in contact with them deposits its moisture, and they become wet with dew. Hence, deposits as will be seen, form on those objects which radiate heat most freely.

"Fig. 16 shows the instrument used for ascertaining the dew point. A glass tube has a bulb blown at each end and one of them, A, is partly filled with ether. This has been boiled and the tube sealed while the vapour was issuing, so that no air is present. Inside this limb is a delicate thermometer; the other limb, B, is wrapped around with muslin. Ether is now dropped upon this, and by its evaporation lowers the temperature. A portion of the ether in A, therefore, distils over, and its temperature, therefore, diminishes likewise. As it sinks, the bulb is watched, and the thermometer read at the moment when vapour begins to form on it. To make this more clearly visible, the bulb is often made of black glass. An ordinary thermometer on the stand of the instrument shows the temperature of the air, and the difference between the two is thus easily noted. By means of pressure and cold, several gases have been liquefied. Carbonic acid, when exposed to a pressure of about thirty atmospheres, becomes a liquid, and if this be allowed to escape into the air, it freezes by its own evaporation and becomes converted into flakes resembling snow. When these are mixed with ether the evaporation is very rapid, and an intense degree of cold is produced, so that mercury may easily be frozen by means of it.

"Another effect of heat is to produce light. Ordinary flame affords an illustration of this fact, the heat arising from the chemical combination being the source of the light. Metals, too, when exposed to a high temperature become luminous. A low red heat is usually assumed at from 1100° to 1300°, with a dazzling white of 2500° to 3000° as it increases. There is, however, great difficulty in measuring these high temperatures with any degree of accuracy. Wedgewood's pyrometer is sometimes employed for this purpose; it consists of metal bars placed about half an inch apart at one end, but a little nearer at the other. Clay cylinders are then made of such a size that when baked at a temperature of 212° they just fit the wider end. When exposed to a very high temperature they contract, and the extent of the contraction is shown by the distance they pass between the bars.

"The air thermometer is, however, more reliable in its indicators. A platinum vessel filled with air is exposed to the source of heat, and the temperature is easily seen by expansion, and ascertained by suitable means, so from this the exhaustion. If a powerful electric current be to pass along a thin platinum wire, it will render it white-hot, and a considerable amount of light will be produced, showing again the luminous effect of heat. We must not, however, suppose that heat is always accompanied by light, or light by heat.

"The electric lamp furnishes us with a very brilliant light, and at the same time an intense heat, so that we have both the luminous and calorific rays in a beam from it. If, now, we cause this beam to pass through a glass filled with a solution of alum, the luminous rays will pass on as before, but all or nearly all the heat will be intercepted. The alum solution serves, in fact, as a filter to remove the thermal rays. Now remove the glass and substitute for it a slab of rocksalt thickly covered with lamp-black, so that no light can penetrate it. On placing a differential thermometer, or thermo-electric pile, in the place where the luminous rays had previously been brought to a focus, we shall find that nearly all the heat has passed through the rocksalt, though the luminous rays have been intercepted.

"By suitable arrangements we may actually succeed in igniting various substances by means of this non-luminous heat. We see, thus, that the luminous and the heat-giving rays may be now noticed, entirely separated from one another.

"We have now to notice the mechanical effects of heat, and to learn how it may be converted into work. To ascertain the mechanical equivalent of heat—that is, the amount of work that can be ascertained and accomplished by a given equivalent of heat—is a difficult proposition. It has, however, been solved, mainly by the researches of Drs. Joule and Meyer.

"The following experiments will give an idea of the process adopted by the latter:

"Take a tube closed at one end, having a sectional area of one square inch, with a piston fitting it air-tight, and capable of moving up and down without friction. Als · a weight supposed to weigh fifteen pounds, twelve ounces, and to be 492 inches from the bottom, the air being at the freezing point.

Now raise the temperature of the air one degree, and since the co-efficient of expansion is $\frac{1}{492}$, the piston will rise one inch, and be 493 inches from the bottom; and thus, for every degree the temperature is raised, the piston will rise an additional inch. If, then, the temperature is raised 492°, the volume of air will be doubled. In this case work has been done by the heat, and that work has consisted in raising the piston and the air above it, which together press with a force of 15 lbs. + 15 lbs. 12 oz. or 492 oz., to a height of 492 inches.

"Now try the experiment in a different way, and ascertain the additional weight requisite to keep the piston in its place, while the temperature varies. We shall find that if the temperature is 1°, one ounce must be added to the piston to keep it stationary; if 2°, two ounces, and so on.

"Hence, if the temperature be raised 492°, 492 ounces must be placed on the piston to keep the volume the same. Compare now these two experiments. In one case we have raised the temperature, the pressure constant while the volume increased; in the other case the volume has been kept constant. The same amount of air has been raised in each to the same temperature; but a different quantity of heat has been required; for investigation shows that if ten grains of any combustible material are required when the volume is kept constant, 14.21 grains of the same material would be required when the pressure remains unaltered. The extra 4.21 grains, then, has been employed in raising the weight, and has thus been converted into work.

"Now suppose we have a vessel of air one square foot in area, and raise it 492° in temperature, the air will occupy double the space; and as the pressure on its surface is 144 × 15 lbs. = 2160 lbs., it will have lifted this weight one foot, or, in other words, performed work amounting to 2160 foot-pounds. The weight of the cubic foot of air is 1.29 ounces, and, as will be explained shortly, the amount of heat required to raise this to any temperature would only raise 0.31 ounces of water to the same temperature, the air having less capacity than the water. The total amount of heat, then, which has received by the air is sufficient to raise 0.31 ounces of water 492°, which is the same as raising nine and-a-half pounds one degree. Of this amount $\frac{4.21}{14.21}$ is, as explained above, employed in driving back the air, while the rest serves to raise the temperature.

"Now $\frac{4.21}{14.21}$ of nine and-a-half pounds is about 2.8 pounds, and thus we find that the amount of heat required to raise 2.8 pounds of water 1° is sufficient to elevate 2160 pounds to a height of one foot. Dividing 2160 by 2.8, we get a quotient of 772 nearly, that is, the quantity of heat required to raise a pound of water one degree will perform work equivalent to 772 foot-pounds. As, however, the thermal unit is usually taken as the quantity required to raise a pound of water one degree in the centigrade scale, the equivalent must be increased by four-fifths, and will be found to be 1390 foot-pounds.

"By a number of various experiments, conducted with great care and patience, Dr. Joule arrived at a very similar result, and we may, therefore, safely take this as the true equivalent. The amount seems very large, especially when we consider the great amount of heat produced by the combustion of various substances. A pound of charcoal, for instance, produces 8000 units of heat, and thus generate a force sufficient to raise a weight of nearly 5000 tons to a height of one foot.

"We do not wonder, since this is the case, that means should have been sought of utilizing the heat of the sun's rays, which on a bright summer's day are calculated to import about five thermal units per minute to each square foot of surface, placed so as to receive them perpendicularly. No important practical results have, however, been obtained at present from these results, and attempts through several inventors have claimed for their machines the power of turning this force to good account.

"It is, however, scarcely probable that, in any economical point of view, they would be able to compete with coal and other fuel."

I think that it is Professor Rankine that says that we owe to George Stephenson the remark that the original source of the power of heat engines is the sun, because the sun's beams furnish the energy that enables plant life to decompose carbonic acid, and so to form carbon and combustible compounds that are afterwards used as fuel.

Having been associated with engineers for several years in business, teaching, etc., I will always have their welfare at heart, and will do everything in my power to advance, elevate and promote their progress in their chosen profession, which is one of the most useful, interesting, and intelligent, as well as honourable, of all the arts that the world of work affords.

I will bring this evening's address to a close by reading you a few leisure moment sketches, from the pen of the celebrated British engineer, Bessemer, and which might aptly be termed an arithmetical romance, and which you will all, I hope, find interesting, showing you he could write with genius even on trivial subjects, as well as invent the most facile process of steel-making, and do with world-renowned credit the many other engineering enterprises connected with his name.

"It would be curious to know how many have brought fully home to their consciousness the significance of that little word billion. Its arithmetical symbol is simple, and without much pretension. There are no large figures, just a modest one, followed by a dozen ciphers, and that is all. Let us briefly take a glance at it, as a measure of time, distance, and weight.

"As a measure of time, I would take one second as a unit, and carry myself in thought through the lapses of ages back to the first day of the year one of our era; remembering that in all these years we have 365 days, and in every day just 86400 seconds of time. Hence in returning in thought back again to this year of grace 1878 one might have supposed that a billion of seconds had long since elapsed. But this is not so. We have not even passed one-sixth of that number in all these eventful years, for it takes just 31687 years, seventeen days, twenty-two hours, forty-six minutes and five seconds to constitute a billion of seconds of time.

"It is no easy matter to bring under the cognizance of the human eye a billion objects of any kind. Let us try in imagination to arrange this number for inspection; and for this purpose I would select a sovereign as a familiar object. Let us put one on the ground and pile upon it as many as will reach twenty feet in height. Then let us place numbers of similar columns in close contact, forming a straight line, and making a sort of wall twenty feet high, showing only the thin edges of the coin. Imagine two such walls running parallel to each other, and forming as it were a long street, we must then keep on extending these walls for miles, nay, hundreds of miles, and still we shall be far short of the required number. It is not till we have extended our imaginary street to a distance of 2386½ miles that we shall have presented for inspection our billion of coins.

"In lieu of this arrangement we may place the flat upon the ground, forming one continuous line, like a golden chain with every link in close contact. But to do this we must pass over land and sea, mountain and valley, desert and plain, crossing the equator and returning round the southern hemisphere, through the trackless ocean, retrace our way again across the equator, then still on and on till we again arrive at our starting point, etc.; and when we have thus passed a golden chain around the whole bulk of the earth we shall be but the beginning of our task. We must drag this imaginary chain no less than 763 times round the globe. If, however, we can imagine all these rows of links laid closely, side by side, and every one in contact with its neighbour, we shall have formed a golden band round the globe fifty-six feet six inches wide; this will represent one billion coins. Such a chain, if laid in a straight line, would reach a fraction over 18,328,445 miles. The weight of it, if estimated at a quarter of an ounce each sovereign, would be 6,975,447 tons, which would require for their transport no less than 2,325 ships, each with a full cargo of 3,000 tons. Even then there would be a residue of 447 tons, representing 64,081,920 sovereigns.

"For a measure of height, let us take a much more familiar unit as our measuring rod. The thin sheets of paper on which the "Times" is printed, if laid out flat, and firmly pressed together as in a well-formed book, would represent a measure of about $\frac{1}{333}$ of an inch in thickness. Let us see how high a dense pile, formed by a billion of the thin paper leaves would reach. We must, in imagination, pile them vertically upward by degrees, reaching to the height of our tallest spires; and passing this the pile must grow higher, topping the Alps and Andes and the highest peaks of the Himalayas; and shooting up from them through the clear clouds, pass beyond the confines of our attenuated atmosphere, and leaps up into blue ether, with which the universe is filled, standing proudly up far beyond the reach of all terrestrial things, still pile on your thousands and millions of thin leaves, for you are only beginning to reach the mighty mass. Add millions on thousands of millions on these, and still the number lacks its due amount. Let us pause to look at the neat ploughed edges of the book before us; see how closely those thin flakes of paper lie; how many of them are in the mere width of a span; and then turn our eyes in imagination upward to see the mighty column of accumulated sheets.

"It now contains its appointed number, and our one billion sheets of the "Times" superimpose upon each other, and pressed into a compact mass has reached an altitude of 47,348 miles."

Another specimen of Sir H. Bessemer's writings is as interesting to us as it is materially beautiful, bearing as it does on the great production of coal in Great Britain in one year:

"The Easter holidays have come round once more, and our boys, with their bright beaming faces, full of mirth and cheerfulness, have been flocking home from school to dear old London, all unmindful of its murky atmosphere, and intent only on the many wondrous sights they hope to see.

"I had just filled some loose sheets, with a view to afford some amusement to my grandsons on their return, when, looking up from my task, I noticed a stream of small bright objects flitting by. The sharp east wind was breaking up the large seed pods on the great Occidental plane tree near my study window, and its taper seeds, with their beautiful little gold-coloured parachutes, were being wafted far away, falling into little chinks and unknown out-of-the-way places; some resting on the bare earth may, perchance, be secured by some blind worm, and made to close the door of its lowly habitation; and in germinating there, may, in after years, when all who now live have passed away, spread its huge arms, and afford a grateful shelter to those who are to come after us.

"Just so the broad sheet you daily publish conveys to every civilized part of the world the thoughts and sentiments of those who lead and form public opinion, while it never fails to give the latest expression of science, literature, and art. Much of all this may, like the flying plane tree seeds, fall on unproductive soil. Yet, who shall say, in that ceaseless stream of intelligence, how many a sympathetic chord of the heart may be touched, or how many thoughts and sentiments so imbibed may germinate, and gaining strength with years may change the whole current of a life, and form the statesman, the scientist, or the man of letters.

"Thus musing, it occurs to me that the statistical results I had arrived at might, perhaps, interest other boys than those for whom they were intended, and if thought worthy of a place in the "Times" might inspire a more than passing interest in an otherwise most uninviting subject.

"The statistics of the coal trade show that during the year 1881 the quantity of coal raised in Great Britain was no less than 154,184,300 tons. When the eye passes over these nine figures it does not leave on the mind a very vivid picture of the reality—it does not say much for the twelve months of incessant toil of the 495,000 men who are employed in this vast industry; hence, I have endeavoured, in a pictured form, to convey to the mind's eye of my young friends something like the true meaning of those figures; for mere magnitude to the youthful mind has always an absorbing interest, and the gigantic works of the ancients fortunately supply us with a ready means of comparison with our own. Let us take, as an example, the great pyramids of Geeza, a work of human labour which has excited the admiration of the world for thousands of years. Though in itself inaccessible to my young friends, we fortunately have its base clearly marked out in the metropolis. When Inigo Jones laid out the plan of Lincoln's Inn.

Fields, he placed the houses on opposite sides of the square just as far from each other as to enclose a space between them of precisely the same dimensions as the base of the great pyramid. Measuring up the front walls of these houses this space is just equal to eleven acres and four poles. Now, if my young friends will imagine St. Paul's Cathedral to be placed in the centre, and having a flagstaff ninety-five feet in height, standing up above the cross, we shall have attained an altitude of 499 feet, which is precisely equal to that of the great pyramid. Further, let us imagine that four ropes are made to extend from the top of this flagstaff, each one terminating at one of the four corners of the square and touching the front walls of the house, we shall then have a perfect outline of the pyramid, exactly the same size as the original. The whole space enclosed within these diagonal ropes is equal to 79,881,417 cubic feet, and if occupied by one solid mass of coal it would contain 2,781,381 tons—a mass less than one-fifth part of the coal raised last year (1881) in Great Britain.

"Higher up the Nile, Thebes presents us with another example of what may be accounted wonderful to have been accomplished by human labour. The great temple of Rameses, at Carnac, with its hundred columns of tweve feet in diameter and over 100 feet in height, cannot fail to deeply impress the imagination of all who, in their mind's eye, can realize the magic colonnade. It may be interesting to ascertain what size of column and what extent of colonnade we could construct with the coal we laboriously sculpture from its solid bed this very year. Let us imagine a plain cylindrical column seventy-five feet in diameter and 500 feet in height, then one year's production of coal would suffice to make no less than 4,511 of these gigantic columns, which, if placed only at their own diameter apart, would form a colonnade which would extend in a straight line to a distance of no less than enough to form fourteen of these tall and massive columns, which, if placed upon each other, would reach an altitude of 700 feet.

"But there is yet another great work of antiquity which our boys will not fail to remember as offering itself for comparison; they have all heard of the great wall of China, which was erected more than 2,000 years ago to exclude the Tartars from the Chinese Empire. This great wall extends to a distance of 1,400 miles, is twenty feet high and twenty-four feet thick, and contains 3,548,160,000 cubic feet of solid matter. Now, our last year's production (1881) of coal was 4,427,186,820 cubic feet, and is sufficient in bulk to build a wall of 200 miles in length, 100 feet high, forty-one feet eleven inches thick—a mass not only equal to the whole cubic contents of the great China wall but sufficient to add 346 miles to its length.

"These imaginary coal structures can scarcely fail to impress the mind of youth with the enormous consumption of coal; and when they are told that in many of its applications the useful effects obtained is not one-fifth of its theoretic capabilities, they will be enabled to form some idea of the vast importance of the economic problem which calls so loudly for solution. They must not, however, fall into the too common error of supposing that the electric light by superseding, is to do away with the use of coal in the production of light, or that the dynamo electric machine will largely replace the steam engine and boiler. Although coal is still our great agent in the production of motive power, it must not be forgotten that Sir W. Thompson has clearly shown that by the use of dynamo electric machines, worked by the falls of Niagara, motive power could be generated to an almost unlimited extent, and that no less than 26,230 horse-power so obtained could be conveyed 300 miles by means of half inch copper wire with a small loss in transmission, what a *magni vista* of legitimate mercantile enterprise this simple fact opens up for our own country. Why should we not at once connect London with one of our nearest coal fields by means of a copper rod one inch in diameter, and capable of transmitting 84,000 horse-power to London, and thus bring up coal by wire instead of rail.

"Let us see what is the equivalent in coal of this amount of water power. Assuming that each horse-power can be generated by the consumption of three pounds of coal per hour, and that the engines work six and-a-half days per week, we should require an annual consumption of coal equal to 1,012,000 tons to that result. Now all this coal would, in the case assumed, be burned at the pit; worth six shillings per ton, for large, two shillings for small, less than one-fourth cost of coal in London. This would immensely reduce the cost in London, and of the motive power now used in London, and at the same time save us from smoke and foul gas. A one inch copper rod would cost £533 per mile, and if laid to a colliery 120 miles away the interest at five per cent. on first cost would be less than one penny per ton on the coal, practically conveyed by it direct to the house of the consumers.

QUALIFICATION OF CANDIDATES FOR CERTIFICATE.

Any person claiming to be qualified to perform the duties of an engineer in steamboats may apply to the Chairman of the Board of Inspection. or to the Inspector of the district in which the applicant resides.

Proofs of service as engineer in the engine room, as engineer on the watch, as apprentice employed on the making and repairing of marine engines, or of employment as journeyman mechanic in some workshop, on the making and repairing of marine engines, must be verified.

No person shall be qualified for a Fourth Class Engineer's Certificate, who is not over twenty-one years of age, and who has not served an apprenticeship of not less than thirty-six months in a steam engine shop, and been employed on the making and repairing of steam engines; or, if he has not served such apprenticeship, he must prove that he has been employed for not less than thirty-six months as a journeyman mechanic in some workshop on the making and repairing of steam engines; or he must have served at least thirty-six months in the engine room of a steamboat as engineer on the watch; or he must have served not less than forty-eight months in the fire-hold of a steamboat of not less than thirty nominal horse-power, as fireman on the watch; and in any of the above mentioned cases twelve months of the time prescribed may have been served in a boiler shop on the making and repairing of steam boilers; he must be able to read, and must write a legible hand; he must understand the construction and operation of the feed water-pump, water-gauges and safety-valves; he must know when a boiler is foaming, and how to stop the foaming; also the danger from neglect to keep a boiler clean, and the usual methods of cleaning it.

A candidate for Third Class Engineer's Certificate must have served an apprenticeship of not less than three years in a marine engine shop, and been employed on the making and repairing of such engines; or, if he has not served such apprenticeship, he must prove that he has been employed for not less than three years as a journeyman mechanic in some workshop on the making and repairing of such engines; in either case he must also have served twelve months in the engine room of a steamboat as engineer on the watch; he must be able to give a lineal description of boilers, the methods of staying them, and the requisite strength of their several parts, and must know the means of repairing them; he must know the method of lining the engine, setting the eccentrics, and adjusting the slides or valves, also the cause of any derangement and the means of remedying it; he must write a legible hand and understand the first five rules of arithmetic.

A candidate for Second Class Engineer's Certificate shall have the qualifications of a third class engineer, with not less than two years' experience as such in the engine room of steamboats of not less than thirty nominal horse-power, as engineer on the watch.

A candidate for First Class Engineer's Certificate shall have the qualifications of a second class engineer, with not less than three years' experience on one or more steamboats of not less than 100 nominal horse-power; he must be competent to calculate the thickness of plates required for a boiler of given dimensions and construction to carry a fixed pressure of steam, and also, the dimensions and construction of the boiler being given, the pressure that it may be allowed to carry; he must be able to calculate the strength of its stays, connections, joints and other parts, and the tensile and crushing strength of the materials used in its construction; he must be able to calculate the required capacity of the feed-pumps, the area of the safety-valves for a boiler of given dimensions, also the power of the engine from a diagram of its working, and to define the position of the crank and eccentrics as indicated by diagram; he must know the relative volumes of steam and water at different temperatures, the chemical constituents of each, its heating and mechanical equivalents and the quantity of air required for its combustion; he must be competent to make a working drawing of any part of an engine, and explain the operation of the engine or any of its parts in connection with the whole; he must be conversant with surface condensation and the working of steam expansively.

Examinations may be upon oath, which any Inspector may administer.

RULES FOR ESTIMATING THE NOMINAL HORSE-POWER OF MARINE ENGINES.

FOR ORDINARY CONDENSING ENGINES.

D = Diameter of cylinder in inches.
N = Number of cylinders.

$$\text{Then } \frac{D^2 \times N}{30} = \text{Nominal horse-power.}$$

FOR COMPOUND CONDENSING ENGINES.

D = Diameter of low-pressure cylinder in inches.
d = Diameter of high-pressure cylinder in inches.
N = Number of low-pressure cylinders.
n = Number of high-pressure cylinders.

$$\text{Then } \frac{(D^2 \times N) + d^2 \times n}{30} = \text{Nominal horse-power.}$$

ARITHMETICAL DEFINITIONS, SIGNS AND QUANTITIES.

Arithmetical signs are characters indicating operations to be performed, and are indispensable for briefly and clearly stating a problem.

$+$, plus, and more, signifying add.
$-$, minus, less, signifying subtract.
$\times$, *multiplied by*, as $2 \times 2 = 4$;
$\div$ or : *divided by*, as $6 \div 3 = 2$, or $6 : 3 = 2$, or $\frac{6}{3} = 2$;
$=$, *equality*, or *is equal to*, as $6 + 2 \times 2 = 16$, and is read thus, "6 plus 2, multiplied by 2, equals 16";
——, or ( ) etc., the vinculum : used to show that all the numbers united by it are to be considered as one; thus, $\overline{6 \times 4} + \overline{3 \times 2} + 1$ means the product of 6×4 is to be added to

the product of 3×2, and the sum of the products to be added to 1.

√ 9, sign of the square root, read "the square root of 9"; for cube $^3\surd = {}^3\surd 9$;

4^2, sign of the square, read "the square of 4";

%, *per cent.*

AN ANGLE is the corner formed by two lines where they meet.

BASE, the lower, or side upon which a figure stands; the foundation of a calculation.

CONCRETE NUMBER, used with reference to some particular object or quantity, as 640 acres, 500 dollars.

CIRCLE, a plain figure comprehended by a single curved line, called its *circumference,* every part of which is equidistant from its centre.

CIRCUMFERENCE, the line that goes around a circle or sphere.

CYLINDER, a body bounded by a uniformly curved surface, its ends being equal and parallel circles.

CUBE, a solid body with six equal square sides. A product formed by multiplying any number twice by itself, as 4×4×4=64, the *cube* of 4.

CUBE ROOT is the number or quantity which twice multiplied into itself produces the number of which it is the root, thus 4 is the *cube root* of 64; sign $^3\surd$.

CURRENCY, the current medium of trade authorized by government.

DIVISION determines how many times any one number is contained in another.

DISCOUNT, the sum deducted from an account, note, or bill of exchange, usually at some rate per cent.

DENOMINATOR, the number placed below the line in fractions, thus, in $\frac{7}{8}$ (seven-eighths) 8 is the *denominator.*

DECIMAL, a tenth; a fraction having some power of 10 for its denominator.

DECIMAL CURRENCY is a currency whose denominations increase or decrease in a ten-fold ratio.

DIVIDEND, the number to be *divided.*

DIVISOR, the number by which the *dividend* is to be *divided.* A *common divisor,* is a number that will *divide* two or more numbers without a remainder.

DIAMETER, a right line passing through any object.

MULTIPLE, a quantity which contains another a certain number of times without a remainder. A *common multiple* of two or more numbers contains each of them a certain number of times, exactly. The *least common multiple* is the *least* number that will do this; 12 is the *least common multiple* of 3 and 4.

NUMBER, a *number* is a unit, or a collection of units. A *prime number* is one that cannot be resolved, or separated into two or more integral factors.

NOTATION, writing numbers.

NUMERATION, reading numbers.

NUMERATOR, the number placed above the line, in fractions; thus, $\frac{5}{9}$ (five-ninths), five is the *numerator*.

POWER—A *power* is the product arising from multiplying a number by itself, or repeating it several times as a factor; thus, $3\times3\times3$, the product, 27, is a *power* of 3. The *exponent* of a *power* is the number denoting how many times the factor is repeated to produce the *power*, and is written thus: 2^1, 2^2, 2^3.

$2^1=2^1=2$, the first *power* of 2.
$2\times2=2^2=4$, the second *power* of 2.
$2\times2\times2=2^3=8$, the third *power* of 2.

PRINCIPAL, the sum lent on interest, or invested.

PER CENT., from *per centum*, signifying by the hundred; hence, 1 *per cent.* of anything is one-hundredth part of it, 2 *per cent.* is one-fiftieth, etc.

SQUARE ROOT is the number which multiplied into itself, produces the number of which it is the *root*. 4 is the *root* of 16; $4\times4=16$.

SPECIE, coin.

SCALE—A scale is a series of numbers regularly ascending or descending.

A SOLID OR BODY has length, breadth and thickness.

SPHERE, a body in which every part of the surface is equally distant from the centre.

TRIANGLE, a figure with three sides.

TERM—The *terms* of a fraction are numerator and denominator taken together.

UNIT—A unit is *one thing*.

VERTEX, the top of a pyramid or cone.

ZERO, a cipher, or nothing.

In arithmetic, the answer in each operation has a distinctive name. In addition it is called the *sum*; in substraction, *difference* or *remainder*; in multiplication, the *product*; in division, the *quotient*.

TENSILE STRENGTH OF PLATE IRON.

(By Mr. Edwin Clark—Brittannia and Conway experiment.)

No. of Plate.	Breaking Weight, square inch.	Ultimate extension in parts of the length.
1. Plate $\frac{11}{16}$ inch thick, neck $1\frac{1}{2}$ long, selected as bad iron; fracture brightly and crystallic brittle, broke readily with a blow from a hammer..................................	22	..
2. From same plate..........................	21	$\frac{1}{40}$
3. Plate $\frac{1}{2}$ inch thick, neck 6 inches, selected as bad iron, containing 2 larninac of crystalline metal, one-third of whole section..	18	$\frac{1}{160}$
4. Plate $\frac{1}{2}$ inch thick, neck 5 inches, selected as good plate; about $\frac{1}{10}$ of the section crystalline..................................	19	$\frac{1}{48}$
5. Plate $\frac{1}{2}$ inch thick, neck 4 inches, iron perfectly uniform and fibrous, supported the weight 15 minutes.................. ...	21	$\frac{1}{18}$
6. Plate $\frac{11}{16}$ inch thick, neck 5 inches, iron good, $\frac{1}{40}$ of the section crystalline........	19	$\frac{1}{36}$
7. Plate $\frac{1}{2}$ inch thick, neck 5 inches, iron fibrous	18.0	$\frac{1}{23}$
8. Plate $\frac{1}{2}$ inch thick, neck 50 inches...........	19.6	$\frac{1}{57}$
9. Plate $\frac{5}{8}$ inch thick, neck 50 inches...........	19.3	$\frac{1}{3}$
10. Plate $\frac{1}{2}$ inch thick, neck 7 inches...........	20.2	$\frac{1}{24}$
11. Plate $\frac{1}{2}$ inch thick, neck 7 inches...........	19.6	$\frac{1}{12}$
12. Plate $\frac{1}{2}$ inch thick, neck 50 inches...... ...	18.7	$\frac{1}{59}$

In all the above the iron was drawn in the direction of the fibre.

VIVA VOCE EXAMINATION OF ENGINEERS.

Question.—What would you do, supposing at any time you could not find any water in the glass gauge or try-cocks?

Answer.—Draw fires immediately, let boiler cool down, then put on the pump and get up steam.

Q.—What is the construction of a feed-pump, concisely told?

A.—Working barrel, solid plunger, suction and discharge valves, etc.

Q.—For what reason will not a pump work when it is hot?

A.—When hot will not form a vacuum.

Q.—On what principle does a feed-pump lift water?

A.—Atmospheric pressure will force the water to follow the plunger.

Q.—What is the effect produced on a pump by derangement of the check valve?

A.—When check valve is out of order, hot water will back out of boiler, which will cause the pump to stop working until all hot water is displaced, which destroys the vacuum.

Q.—Where should the manhole and mudplates be placed, and why?

A.—On the inside, because the pressure is on the inside, they are safest and more easily secured.

Q.—Explain what is meant by a surface blow-off?

A.—A surface blow is a cock and pipe fitted on boiler about six inches below the water line, to blow out supersalted water or dirt, in order to prevent the deposition of salt or scale upon the plates.

Q.—On what part of a boiler should the main blow-off be?

A.—Main blow-off should be placed on the bottom of a boiler.

Q.—Explain the manner of cleaning the scale from a boiler?

A.—Draw the fires all out, and blow the water out of the boiler, take off manhole doors, take scaling hammers, go inside and knock off all scale upon the plates, and wash out with hose and force-pump.

Q.—How often should a boiler be cleaned and scaled?

A.—As often as required; it should, if possible, be attended to once a week, so as to keep the scale off and the iron from injury.

Q.—What are the dangers of not keeping the boiler clean and well scaled?

A.—Scale will collect and burn the boiler, as the water will not get to the iron, the bottom of the boiler will decay soonest, the furnace tubes and uptake wear out before the other parts.

Q.—What often causes boiler explosions, also injures them, and in what way should an engineer guard against them?

A.—A defective boiler, and carrying too high a pressure, and not keeping the boiler clean inside and out, getting steam too quickly from cold water, etc. Care, attention, knowledge and experience.

Q.—Explain what foaming and priming are?

A.—Foaming is when the water becomes very much agitated, caused by mixed or dirty water; priming is when the steam and water mixes and go into the engine.

Q.—What style of boiler require more watchfulness than others?

A.—Badly constructed boiler will require the most watching, so as to keep the water to a uniform height, and prevent foaming.

Q.—What danger may there be in raising the safety-valve of a boiler suddenly?

A.—Raising the safety-valve too suddenly is dangerous, as the pressure being relieved on that particular area the rest of the steam rushes to take its place, and escape by the outlet, carrying water with it, may injure the boiler by its action.

Q.—What make of boiler primes badly?

A.—A boiler with bad circulation, and not enough steam space.

Q.—What height of water should be carried over top of heating surface in a boiler?

A.—From five to nine inches; of course it all depends on style of boiler.

Q.—What is the danger of coming to a wharf with a foaming boiler?

A.—The danger is when the engine is stopped the water will fall too low.

Q.—When your boiler is foaming how do you find what water you really have in boiler?

A.—Stop the engine and the water will come to the level of what is in the boiler.

Q.—What may cause the glass or try-cocks to deceive the engineer?

A.—The water gauge-glass may deceive the engineer by the top or bottom cock getting stopped; try-cock by not blowing long enough.

Q.—Explain the construction of the glass and try-cocks, also the principle of the steam gauge?

A.—They are brass cocks, screwed into the boiler; water gauge-glass is attached to boiler with two brass cocks and packing glands and drain cock; the steam gauge is an elliptical tube, connected at one end to a steam pipe and the other to a pointer.

Q.—How would you lay an engine up for the winter?

A.—Blow off boiler, clean out all dirt, clean bright parts of engine, paint with white lead and tallow, and put in a dry place; empty all pipes.

Q.—What is the manner of lining an engine?

A.—With line, straight edge and square; start from cylinder centre.

Q.—Explain the mode of setting the eccentric?

A.—Put crank on top of centre, give valve lead required, turn eccentric round to place, bottom centre same way.

Q.—How would you find out if the crank pin is set true in crank; and if connecting rod is properly hung?

A.—With straight edge and square, working from face of crank if true; if not from shaft, disconnect from crank pin will show if hung true.

Q.—What rule is used for calculating the area of safety-valve?

A.—British Board of Trade rule, which is, "Half a square inch to every square foot of grate surface."

Q.—How would you calculate the throw of the eccentric?

A.—$P \times L \times 2 = T$;—size of steam port one inch, lap of value one-eighth of an inch, the throw of the eccentric would equal two and a quarter inches.

Q.—Give the formula for to calculate the horse-power of a steam engine?

A.—$D^2 \times S \times 2R \times P \times$ constant multiplier equal to HP. Example: $36''^2 \times 6 \times 50$ $(25 \times 2) \times 40 \times .0000238$ equal to 370 horse-power; .0080238 equal to 33000, divided into decimal .7854, so save multiplying by .7854 and dividing by 33000.

Q.—How would you work an engine with broken air pump and foot valve.

A.—High-pressure.

ENGINEERS' EXAMINATION.

"Multiply twenty-five hundredths by twenty-five hundredths."

The above ponderous calculation is still on the examination paper for engineers for Canadian certificates to work out.

Notice is hereby called to it, to explain that its former use, that of trying, by its calculation, to gauge the applicant's knowledge of multiplication of decimals, is now nearly gone, for two reasons: First, nearly all engineers now understand and work their calculations by decimals; Secondly, having been in use as a set calculation question since 1867, it has been handed from one to another, and so every engineer, or applicant, knows the "dodge" of prefixing the cypher to the left hand side before pointing off, whether he understands multiplication of decimals or not.

Example: .25 × .25.

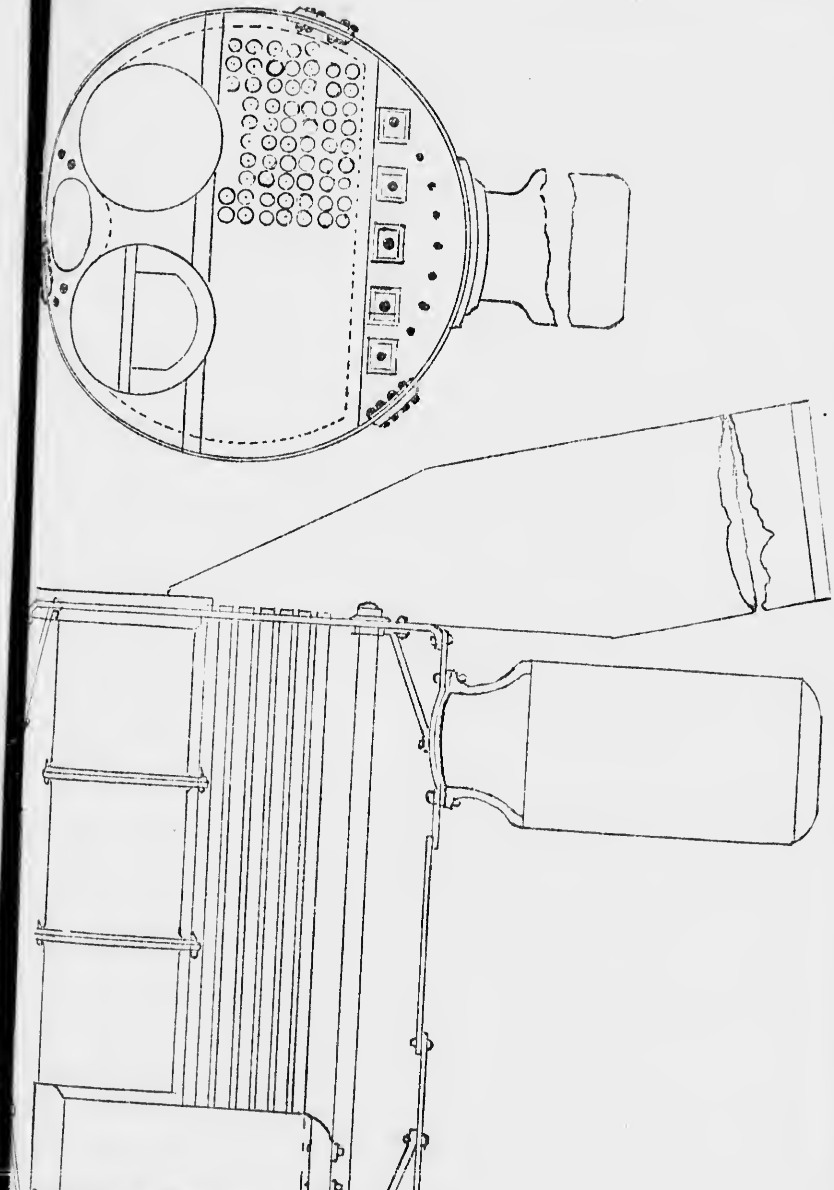
```
 .25=twenty-five hundredths.
 .25   "      "      "
 ---
 125
 50
 ----
.0625 six hundred and twenty-five ten thousandths.
```

RULE.—Multiply as though there were no decimals and then remove the decimal point in the product as many places to the left as there are decimals in both the multiplicand and the multiplier.

Examples: 5.63 × .0005 =.0002815 : .012 × .012 =.000144.

Calculate the thickness of plate required for a boiler of given dimensions. See plate No. 1.

This calculation can be figured according to the old rule of



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42 : 100 :: $\frac{1}{4}$, as in constructing a boiler, the best manner is now generally followed, but a rule adduced from the rule for the pressure allowable on shell of boiler of the Steamboat Inspection Act of 1882, by infusion, is the best and most approved method, and the answer can be brought straight by using the radius, or half the diameter of the boiler, instead of dividing the result by 2, because of their being two sides to a boiler.

Examples with answers proportioned:

Diameter.	Pressure.	Thickness.
80	$65\frac{3}{4}$	$\frac{5}{16}$ (.3152) ∴ 80 : 42 :: 65.75 = $\frac{5}{16}$
85	70	$\frac{6}{16}$ (.3541) ∴ 85 : 42 :: 70 = $\frac{6}{16}$
84	$62\frac{1}{2}$	$\frac{5}{16}$ (.3152) ∴ 84 : 42 :: 62.5 = $\frac{5}{16}$

Calculate the thickness of plate required for a boiler 36″ diameter and 145 lbs. pressure.

RULE.—$\frac{\text{Inside diam. of boiler} \times \text{pressure} \times \text{factor safety}}{60000 \times .70} = 2T$ $\div 2 =$ thickness of plate for boiler.

```
                    36 diameter of boiler.
                   145 pressure per square inch.
                  ----
                   180
                  144
                  36
                  ----
                  5220
 60000               5 factor of safety for iron when made
   .70            ----          in the best manner.
------42000)26100.00(.621 ÷ 2 = .315 = 5/16″ plate.
            252000
            -------
              90000
              84000
            -------
              60000
              42000
            -------
               8000
```

For steel boiler, taking same dimensions as preceding sum, it would be $\frac{1}{4}$ of an inch thickness required.

```
     5220
        4 factor of safety for steel when made in best
                                                   manner.
     ------
42000)20880.0(.4971421
      16800
      -------
      408000
      378000
      -------
       300000
       294000
       -------
         60000
         42000
         -------
         180000
         168000
         -------
         120000
          84000
         -------
          46000
          42000
         -------
           4000
```

```
2)4971421 decimal.
  ---------
  .24857015 thickness plate.
         16
  ---------
  149142630
  24857105
  ---------
 3.97713680 nearly ¼ of an inch.
 -
16
```

What thickness of plate for an iron boiler 9 feet diameter, 112 lbs. pressure, made in best manner?

$$\frac{108\times112\times5}{60000\times.70}\div2=\frac{3}{4}''\text{ plate.}$$

```
               112
               108
               ---
               896
              1120
              -----
             12096
60000            5
   70        ------
------42000)60480.0(1.44÷2 = 72
```

```
42000)60480.0(1.44÷2 = 72
      42000              16
      ------             --
      184800            432
      168000            72
      ------            --
       16800            11.52 nearly 3/4
       16800            --
      ------            16
       .....
```

Formula of rule for iron boilers:

$$\frac{D\times P\times FS}{TS\times .70}=2T\div 2=T$$

Factor of safety for iron 5 and for steel 4; rule the same for thickness of plate with this exception.

Calculate the thickness required for a boiler 42″ diameter and 75 lbs. pressure per square inch, made of iron in best manner.

```
      42 diameter boiler.
       5 factor safety.
     ---
     210
      75 pressure.
    ----
    1050
   1470
   -----
42000)15750.0(.375÷2 = .1875 = 3/16 thickness plate.
      126000
      ------
       315000
       294000
       ------
        210000
        210000
        ------
```

Second method, same sum:

```
      21 radius boiler.
       5
     ---
     105
      75
     ---
     525
    735
    -----
42000)787500(.1875 = 3/16 thickness plate.
    42000
    ------
    367500
    236000
    ------
     315000
     294000
     ------
      210000
      210000
      ------
      ......
```

The letters signify the following expressions:

D—Diameter.
F S—Factor of safety.
BM—Best manner.
T S—Tensile strength.
T—Thickness.
2 T—Twice the thickness.
.·.—Then.

Calculate the thickness of plate required for an iron boiler forty-two inches diameter and 150 pounds pressure :

```
 42
150
----
2100
42
----
6300
```

6300
5

6000 × .70=42000)31500.00(.75÷2=.375=$\frac{3}{8}$ or $\frac{6}{16}$
29400.00

210000
210000

......

Calculate the thickness of plate required for an iron boiler forty-two inches diameter and 100 pounds pressure, made in best manner :

42
100

4200
5

42000)21000.0(.5÷2=.25=$\frac{1}{4}$″ plate.
21000.0

....

Same dimensions, punched holes, not good and fair in longitudinal seams, lap seams, and double riveted=C .3., E .75., K .2.,=1.25 total to be added to factor safety=6.25. See "S. B. Inspection Act of 1882," page 23 :

6.25 factor of safety in this case.
42000=42 × 100

1250000
250000

6000 × .70=42000)262500.00(.625÷2=.3125=$\frac{5}{16}$″ plate.
252000 16

105000 18750
84000 3125

210000 5.0000
210000

.... 16

Calculate the thickness of plate required for a boiler forty-two inches diameter and 100 pounds pressure, made in best manner:

```
                42 inches diameter of boiler.
                100 pressure per square inch in pounds.
               ----
 60000         4200
   .70            5 factor of safety for iron.
 ------       -----
4200.00)210000(.5÷2=.25=1/4" thickness of plate.
        210000
        ------
        ......
```

Rule formulated:

$$\frac{\text{Inside diameter of boiler} \times \text{pressure} \times \text{factor safety.}}{60000 \text{ lbs. TS} \times \text{percentage strength } (.70).} = \text{double}$$

thickness of plate (two sides of boiler) ÷ 2 = thickness of plate required.

Above sum abreviated:

$$\frac{42 \times 100 \times 5}{60000 \times .70} = .5 \div 2 = .25 = \tfrac{1}{4}\text{" plate.}$$

Second method:

```
          21 radius of boiler.
          100 pressure.
          ----
          2100
             5
          -----
42000) 105000 (.25=1/4 inch thickness of plate.
        84000
        ------
        210000
        210000
        ------
        ......
```

Foregoing method abbreviated :

$$\frac{21 \times 100 \times 5}{60000 \times .70} = .25 = \tfrac{1}{4}'' \text{ thickness.}$$

Second method of how to calculate the thickness of plate for boilers ofdifferent diameters and pressures, etc.:

$$\text{Formula: } \frac{(d \div 2) \times FS}{TS \times .70} = T$$

RULE.—The radius or half the diameter of boiler, multiplied by factor of safety, multiplied by the working pressure per square inch, in pounds, divided by the tensile strength of the iron or steel, in pounds, per square inch, multiplied by the percentage of strength of plate equal to thickness.

Factor of safety for iron 5 ; for steel 4 ; tensile strength of plate, per square inch, 60,000 pounds ; percentage of strength of joints .70.

These are standard for boilers made in the best manner, according to Act of 1882.

EXAMPLE.—Boiler seven feet diameter, pressure 100 pounds; find thickness :

```
                 7 ft.
                12
                --
               2)84 diameter of boiler, in inches.
                 --
                 42 radius, or half diameter of boiler.
                  5 factor safety for iron, B.M.
                 --
  60000         210
    .70         100
  -------     ------
42000.00)210000(.5=½" thickness of boiler plate.
         210000
         ------
         ......
```

By first method it would stand :

$$\frac{84 \times 5 \times 100}{60000 \times 70} = 1'' \div 2 = .5 = \tfrac{1}{2}'' \text{ plate.}$$

How to calculate the pressure allowable on boilers of different diameters and thickness of plate :

Taking iron at 60,000 pounds, tensile strength, per square inch, and using .70 ; when made in best manner, and using, therefore, 5 as factor of safety for iron, and 4 factor of safety for steel.

$$\frac{60000 \times 70 \times \text{twice the thickness of plate}}{\text{Inside diam. of boiler in inches} \times \text{factor safety.}} = \text{pres. per sq. in.}$$

See "Rules and Regulations" of Steamboat Inspection Act, 1882, page 23.

The working pressure of a boiler is arrived at by a series of calculations of the strengths of the various parts, their workmanship, materials, and dimensions.

Rule for getting the pressure allowable on boilers made in best manner, is in its results similar to the proportion, 42 : $\frac{1}{4}$ :: 100 pounds, but defective workmanship, material, etc., require the rule given in "Act," on account of the difficulty of applying the percentages for defects in the old rule of proportion for comparative strength.

Rule, according to "Act," as adduced from Board of Trade Formula, and made to meet Canadian standard:

RULE.—Tensile strength of iron in pounds, multiplied by calculated percentage of joints (taking the smaller percentage) then multiply by twice the thickness of plate in inches, and divide by the inside diameter of boiler in inches, multiplied by the factor of safety equal to pressure to be allowed per square inch on the safety-valve, as a working pressure.

$$\text{Formula : } \frac{TS \times .70 \times 2T}{D \times FS} = P$$

$$\text{Being } \frac{\left\{\begin{array}{l}\text{Tensile strength 48000 lbs.} \times .70 \text{ percentage of} \\ \text{strength of joint} \times \text{twice the thickness of plate.}\end{array}\right\}}{\left\{\begin{array}{l}\text{Inside diameter boiler in inches} \times \text{the safety} \\ \text{factor (whatever it may be).}\end{array}\right\}} =$$

Equal pressure allowed for the boiler to carry according to the Steamboat Inspection Act of 1882.

TS. in lbs. p. c. 2T(¼ in. × 2)

$$\therefore \frac{60000 \times 70 \times .5}{42'' \times 5} = 100 \text{ lbs. pressure per square.}$$

D= FS equals P

Inch, when made in best manner, vide S. B. Inspection Act, pages 23–4.

Calculate the pressure allowable on a boiler sixty (60″) inches diameter, seven-sixteenths ($\frac{7}{16}$″) of an inch thickness of plate.

$\frac{7}{16}$=.4445 × 2=.889=twice thickness of plate.
60000 × .70=42000, value of plate.

```
                 1778000
                 3556
  D   FS
60 × 5=300)37338.000(124.46, or 124½ lbs. per square
           300            inch pressure allowable.
           733
           600
           1338
           1200
            1380
            1200
             1800
             1800
             ....
```

Proof.—Calculate the thickness of plate, according to the rule laid down in the Act, for a 60″ diameter and 124.46 lbs. pressure:

$$\frac{60 \times 124.46 \times 5}{60000 \times .70} = .\frac{889}{2} = .4445 = \frac{7}{16}''$$


2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.8
1.6
1.1
1.0

Diameter of boiler 28″ plate, ¼″ thickness of plate; compute the pressure allowable per square inch, as working pressure.

```
                    60000 tensile strength in lbs. per square inch.
                      .70 percentage.
Diameter          ———————
 boiler=28″       42000.00 value of boiler plate.
Fac. saf'y 5             .5=double the thickness of plate.
 ———              ————————
             140)21000.000(150 lbs. pressure per square inch.
                 140
                 ———
                  700
                  700
                  ———
                    0
                    0
                    —
                    .
```

Diameter of boiler 84 inches, ¼ inch thickness of plate.

```
                  60000 lbs. tensile strength of iron per sq. inch.
                    .70
                ————————
Diam. 84″       42000.00 value of iron.
 F S= 5                .5″ double thickness because of the two
 ————           ————————        sides of boiler.
            420)21000.000(.50 lbs. pressure per square inch.
                2100
                ————
                   0
                   0
                   —
                   .
```

Comparative strength of boilers of different diameters made in best manner of ¼ of an inch thickness of plate:

Diameter	42	inches	= 100	lbs. pressure	per square	inch.
"	28	"	150	"	"	
"	56	"	75	"	"	
"	70	"	60	"	"	
"	84	"	50	"	"	
"	65	"	64	"	"	

Diameter 78 inches $\frac{3}{4}''$ thickness of plate=161 lbs. pressure.
" 56 " $\frac{3}{8}$ " " =112½ "
" 84 " $\frac{7}{8}$ " " =175 "

$$\text{Rule abbreviated}\frac{60000 \times .70 \times 75^{(\frac{3}{8}{}^{2})}}{56 \times 5}=112.5 \text{ lbs. pressure.}$$

Calculate the pressure allowable on a boiler eighty-four (84″) inches diameter, thickness of plate one-half inch (½″), made in best manner:

```
        60000
          .70
       ---------
 84    42000.00
  5             1=½=.5×2
 ---   ---------
420)   42000.00(100 lbs. pressure.
       420
       ----
         00
         00
         --
         ..
```

$$\text{Abbreviated}=\frac{6000\times 70\times 1}{84\times 5}=100 \text{ lbs. pressure.}$$

Second method for calculating the pressure allowable:

RULE.—Tensile strength of iron, minus the percentage, multiplied by the decimal of the thickness of plate, divide by radius or half diameter of boiler in inches, multiplied by factor safety=pressure per square inch, allowable.

$$\text{Formula: }\frac{TS\times .70\times T}{\text{radius}\times FS}=P$$

EXAMPLE.—A boiler $\frac{7}{16}$ inches thickness of plate and 60 inches diameter; compute pressure allowable for a boiler when made in best manner:

$\frac{7}{16}$=.4445

```
                 42000=60000 × 70
            ----------
             8890000
            17780
:2)60       ----------
—30 × 5=150)18669.0000(124.46 pressure lbs. per square inch.
            150
            ---
             366
             300
             ---
              669
              500
              ---
               690
               600
               ---
                900
                900
                ---
                ...
```

GENERAL EXAMINATION QUESTIONS FOR ENGINEERS.

Question.—Give the rules for computing the nominal horse-power of engines?

Answer.—For compound engine, square the cylinder of high-pressure, and add the square of the low-pressure, and divide by thirty; for condensing or non-condensing engines, square the cylinder, and divide by thirty; diameter of cylinders to be expressed in inches in all cases.

Q.—Give the rule for the pressure allowable on boilers, also the thickness of boiler-plate required?

The tensile strength has been changed as follows, from sixty thousand to forty-eight thousand pounds per square inch with the grain, forty-two thousand pounds across the grain.

A.—Sixty thousand multiply by seventy per cent. multiplied by double the thickness of plate, divide by diameter of boiler in inches multiplied by the factor of safety equal to pressure per square inch, and for thickness of plate just the reverse of this proceeding, which gives: $\frac{D \times P \times FS}{60000 \times .70} = \frac{2T}{2} = T$

Q.—What is the tensile strength of iron and steel?

A.—Cast iron about 15,000 pounds or six and three-quarter tons; wrought iron from 50,000 to 65,000 pounds; best steel, say about 130,000 pounds; good bar iron 60,000 pounds, or twenty-seven tons; boiler plate from twenty to twenty-eight tons.

Q.—What is the crushing strength of iron and steel?

A.—Cast iron 100,000 pounds, or forty-four and-a-half tons; malleable iron 27,000 pounds, or twelve tons; the crushing strength of steel is about double its tensile strength; in all strengths the strain is per square inch; iron and steel has great ranges, according to make, etc.

Q.—What pressure is allowed per square inch on stays?

A.—"Six thousand pounds to each effective square inch of section of the stays supporting it."

Q.—What is the rule given in the Act for the area of diagonal stays? (Canadian Act of 1882.)

A.—"Find the area of a direct stay needed to support the surface, multiply this area by the length of the diagonal stay, and divide by the length of a line drawn at right angles to the surface supported to the end of the diagonal stay, the quotient will be the area of the diagonal stay required."

Q.—Give the rule for computing the contents of a pump?

A.—Area of pump multiplied by stroke in inches.

Q.—What is heat?

A.—That property of bodies by which they grow hot, and is thought to consist of motion of the molecules of which the bodies consists.

Q.—How is heat generally produced?

A.—By chemical, mechanical and electrical action.

Q.—In what three ways is it conveyed?

A.—By connection, conduction and radiation.

Q.—What is the mechanical equivalent of heat?

A.—Heat and mechanical energy are mutually convertible, and heat requires for its production by its disappearance mechanical energy in proportion of 772 foot-pounds for each British unit of heat.

Q.—What is a British heat unit?

A.—The quantity of heat which corresponds to an interval of one degree of Fahrenheit's scale in the temperature of one pound of pure liquid water at and near its temperature of greatest density (39° F.)

Q.—Explain the action that ensues when a fire is lighted under a boiler containing cold water?

A.—The heat generated by the chemical action of combustion passes from the fire, and the gaseous products of combustion to the iron of the boiler, through the iron of the boiler to the surface in contact with the water and thence into the water.

Q.—Whose tables are generally used to obtain the quantity of heat required to evaporate a given quantity of water and the volume of steam and water, etc.?

A.—Regnault and Fairbairn's and Tate's.

Q.—How much heat is needed to boil a pound of water at 200 pounds per square inch, boiler pressure, than at five pounds, feed 60° F. in each case?

A.—At 5 pounds it would require 1,123 units, viz.:

	UNITS.
Heat required to raise 1 lb. water from 32° to boiling at 5 lbs.=	196
Deduct heat to raise from 32° to 60° not used=	28
Heat to raise from 60° to boiling	168
Internal work of evaporation	882
External work of evaporation	73
	1,123

At 200 pounds it would be 1,171, viz.:

Heat required to raise 1 lb. water from 32° to boiling at 200 lbs. per square inch	359
Deduct heat to raise from 32° to 60° not used	28
	331
Internal work	756
External work	84
Heat to boil 1 lb. water at 60° at 200 lbs.	1,171

1171 − 1123 = 48 units.

$\frac{48}{1123}$ = 4 per cent. nearly.

Q.—How much fuel can be saved by raising the temperature of the feed-water from 100° F. to 200° F., the boiler pressure being 120 pounds per square inch?

	UNITS.
A.—Total heat for 120 lbs	1188
Deduct in the one case the units not used in raising the water from 32° F. to 100° F	68
Required from 100° F. to boil at 120 lbs	1120
In the other case deduct for not using	169
Required to boil at 120 lbs. from water @ 2°=	1,019

Difference 1120 : 1019=101 units=9 per cent.

Q.—Why is so much difficulty experienced in maintaining high-pressure than low-pressure?

A.—High-pressure steam leaves the boiler more easily and, therefore, if employed in an engine, the engine can be made to do more work thereby. If, in running a boat, the boat going faster the engines use more steam; if, in heating a building, the radiators act more energetically with higher pressure, transmit more heat and condense more steam.

Q.—What causes boiler explosions?

A.—Steadily accumulating pressure; steam, etc., formed from sudden contact of water with red hot metal, electrical; the decomposition of water or steam into hydrogen and oxygen, etc.

Q.—In what manner does priming and foaming occur in boilers?

A.—"As bubbles of steam formed on the hot iron of a boiler rise through the water to the surface, breaking and scattering spray, a portion of water thus thrown up into the steam room is carried along with the steam, and unless more heat be supplied to evaporate this water it increases the volume caused by the steam condensed in the pipes in the upper portion of the boiler. This water carried with the steam is said to be entrained with it, and is called 'priming' by many writers. When the proportion of water becomes so large as to be evident in the action of the engine, it is called by some foaming. This last occurs from dirty water, etc."

Q.—What is the rules for external pressure on flues?

A.—"The product of 90,000, multiplied by the square of the thickness of the plate in inches, divided by the length of the flue or furnace in feet, plus 1, multiplied by the diameter in inches, will be the allowable working pressure per square inch in pounds, provided it does not exceed that found by the following formula: The product of 8,000, multiplied by the thickness of the plate in inches, divided by the diameter of the furnace or flue in inches, will be the working pressure per square inch in pounds."

Q.—What is a steam engine indicator?

A.—It is an instrument designed to register automatically upon paper the pressure of steam, etc., in the cylinder at every point of the piston's stroke; the information drawn from its cards afford a variety of useful facts relating to the condition and working of the engine.

Q.—What can be ascertained by the use of the indicator?

A.—The proportion of boiler pressure utilized, also if steam and discharge passages are of correct size; whether the piston is tight, the pressure on piston and average throughout the stroke, also if it is well drawn and the final pressure and the amount of vacuum, the consumption of steam for engine and machinery or any part of machinery, effective work of lubricants.

Q.—What is the method of calculating the average or mean pressure from an indicator card?

A.—Divide the diagram into ten equal numbers of spaces by lines drawn at right angles to the atmospheric line, and measure spaces between the lines of diagram or between atmospheric line and diagram outlines, both up and down, separately, and divide by ten, equal to mean pressure or average pressure, add before dividing, and where the vacuum and steam are computed, separately add and divide both by ten, and add the results for the mean total pressure; use the scale corresponding to spring used, or take a narrow strip of a straight edged paper, place it across the diagram, and let one end of strip come directly over the atmospheric line, then with a sharp pencil, mark the length of first space, etc., and so proceed until the length of each space has been added to the first; then measure with a rule from end of paper to the last pencil mark; divide this by the number of spaces, and multiply by the number of spring in use, and the result is the average impelling pressure per square inch. Proceed in like manner to get resisting pressure, etc. It is usual in condensing engines to find the value of steam and vacuum pressures separately.

Q.—What is meant by a boiler of a given number of horse-power?

A.—One capable of evaporating that number of cubic feet of water per hour.

Q.—What is mechanics?

A.—It is the science of force applied to a material body or bodies.

Q.—What is meant by force in mechanics?

A.—Force is the power or agent, whatever be its nature, by which motion is produced in a body, or a tendency to motion accompanied by strains or pressures in its parts.

Q.—What is meant by power in mechanics?

A.—Power is the product of pressure and motion; or the result of a certain pressure acting at a certain velocity.

Q.—Into what two branches is mechanics divided?

A.—Statics, at rest or balance; and dynamics, moving or having motion or velocity.

Q.—How many kinds of levers are there?

A.—Three orders: 1st, When the fulcrum is between the power and resisting weight: as spade, pump, handle. 2nd, When fulcrum is at one end, and the weight nearer to it than power; oar of boat, nut-crackers, etc. 3rd, When the fulcrum is again at one end, but power nearer to it than weight, as in the safety-valve. Compound levers are used to increase the power.

Q.—What pressure is allowed on plates forming flat surfaces?

A.—Rule given is $\frac{C \times (T+1)^2}{S-6}$ = working pressure in pounds per square inch.

T=Thickness of plate in sixteenths of an inch;

S=Surface supported in square inches;

C=100; but when the plates are exposed to the impact of heat or flame, and steam only is in contact with the plates on the opposite side, C is to be reduced to fifty.

Q.—What is the rule for the area of safety-valves?

A.—"The area of any locked safety-valve, or the joint areas of any locked safety-valves to any boiler, made or placed on board after the passing of the Act of 1882, shall not be less than half a square inch for each square foot of grate surface in or under the boiler."

Q.—What is the formula for the working pressure to be allowed on girders?

A.—Formula given in Act is $\frac{c \times d^2 \times T}{(W-P) D \times L}$ = working pressure.

W=Width of combustion box in inches;

P=Pitch of supporting bolts in inches;

D=Distance between the girders from centre to centre in inches;

L=Length of girders in feet;

d=Depth of girders in inches;

T=Thickness of girders in inches;

C 500, or 750, or 850, according to number of supporting bolts used.

Q.—What rules are given for the strength of joints?

A.—$\frac{(\text{Pitch}-\text{Diameter of rivets}) \times 100}{\text{Pitch}}$ = Percentage of strength of plate at joint as compared with solid plate.

$\frac{(\text{Area of rivets} \times \text{No. of rows of rivets}) \times 100}{\text{Pitch} \times \text{thickness of plate.}}$ = Percentage of strength of plate at joint as compared with the solid plate.

Q.—In what manner are steam gauges constructed?

A.—Steam gauges for indicating the pressure per square inch in the boiler are made either with diaphragm or as a spring against which the steam pressure acts or presses, or by a flattened curved tube which tends to become circular in section with increase of pressure.

Q.—Explain what gauge cock and glasses are used for, and where and how placed?

A.—"Gauge cocks are put in at different levels near the water line. The lowest is usually put in so that a full gauge of water lies over the danger point, or highest metal exposed to the direct action of the hot gas on the second return thereof. The cocks are in number from two up, three or four in all, being the common number. The upper one is placed at as high a level as it is thought can be used. The brass fittings in which the latter are inserted should be provided with four valves, one between the glass and boiler at each end of the tube, and one at each end in the line of the tube, so it can be cleaned by washing from either end and a rod can be run through it. The tube is packed in place by gum washers and double nuts. Specially soft glass has to be used, and great care taken not to separate and scratch the glass, or a break is sure to happen. By shutting off the glass from the boiler it can be easily replaced." From "Steam Making," by Prof. Chas. Smith, C. E., M. E.

Q.—What manner of safety-valves are generally used on steam boilers?

A.—Direct loaded, weight and lever and spring 'pop' valves.

Q.—What may be said as regard to the application of steam jets to induce a current of air for a draft?

A.—"Application of a steam jet to induce a current of air for draft is nearly as old as the locomotive with which it originated and to which its use now is almost restricted, and to boilers of the same class where a sudden call for steam can be rapidly met. In the most simple form, a pipe is led from the boiler to the stack, if of iron, if not, to some of the flues, or tubes, which is terminated by a reducer with a three-eighth inch or quarter inch nipple, sufficing to raise the gauge from twenty to ninety pounds in seven minutes for a 100 horse-power engine. Chimney used in this case was eighteen inches diameter and twenty-five feet high." From "Steam Making," by Prof. Chas. Smith, C. E., M. E. Mr. I. A. Langridge, M. I. C. E., comes to the following conclusion in regard to plain jets and nozzles: 1. The action is due the friction of one fluid on the other, and that by dividing the jets the surface of contact of the fluids is much increased for the same masses of fluid; or the same draft may be produced with less steam. 2. The effect of the draft is increased by lengthening the chimney, but the effect is smaller from four diameters to eight diameters than less than four diameters above eight there is a falling off. 3. He states that the draft measured in inches of water, inches of diameter and pounds per square inch above the atmosphere, may be computed as follows: Draft equals thirty-seven times the fifth power of the third power root of the diameter of the blast pipe times the fourth power of the fifth root of the pressure, divided by the square of the diameter of the chimney.

Q.—What are the chemical constituents of coal?

A.—Carbon, hydrogen, oxygen, nitrogen, sulphur and ashes, which form the result from combustion.

Q.—Of what is air composed that cause coal to burn?

A.—Nitrogen and oxygen, this latter causes combustion.

Q.—Of what is water composed, and does its evaporation under coal assist any?

A.—Oxygen and hydrogen, the oxygen would assist as in the air.

Q.—In what manner may the size pump required for boiler be calculated from the boiler's heating surface?

A.—Assuming that ten square feet will evaporate one cubic foot per minute, and that the boiler has 1,200 square feet heating surface.

```
10)1200          1728
   ————             2
 60)120          ————
   ————     =³√3456(15 the length of stroke of pump.
     2             1
                 ————
  1×300 )        2456
1×3×30  } 475=)2375
   5×5  )        ————
                   81
                   ==
              ²√15(3.8729  diameter of pump,
                  9                take 3⅞"
                 ————
             68)600
                544
                ————
            767)5600
                5369
                ————
```

5369

7742)23100
15484

77449)761600
697048

64559

$3\frac{7}{8}^2 \times .7854 \times 15 = 176.89$ contents of pump.

176.89)3456000(19.53
17689

168710
159201

95090
88445

66450
53067

3383

Size pump:—$3\frac{7}{8}''$ diameter, 15 stroke, 20 revolutions per minute.

Q.—Into what three general divisions are engines divided?
A.—High-pressure, or non-condensing, low-pressure or condensing, and compound engines.
Q.—What is meant by the working of steam expansively?
A.—The cutting off the supply of steam at any point of the stroke in the cylinder, and allowing the steam to expand to the end of the stroke; it saves steam but diminishes the power of the engine while increasing the efficiency of the steam. For instance, if the steam be cut off at half stroke, there will be only half the quantity of steam used, but there will be more than half the power exerted, because the steam in expanding does some work, and that is a clear gain. If the steam is cut off at half stroke, it will be half the initial pressure at the end of the stroke, whatever that may be; if at third of the stroke it will be one-third and so on, according to the well-known law of pneumatics—"the pressure of elastic fluids varies as the space into which they are expanded or

compressed." Thus, if a cubic foot of steam at ten pounds pressure be compressed into one-half a cubic foot, the pressure will be twenty pounds, but if expanded into two feet it will be only five pounds, provided the temperature remains unaltered; in estimating the pressure in a condensing engine the atmospheric pressure must be included. Thus, if the steam gauge shows twenty-eight inches (two inches equals one pound pressure) the initial pressure on each square inch of the piston will be 20+14=34 pounds per square inch. Rule by which can be found the amount of gain derived by expansion by one operation. Divide the distance through which the steam expands by the distance the piston travels before the steam is cut off (which call one); the hyperbolic logarithm of the quotient is the increase due to expansion. According to this rule it will be seen that if a gain quantity of steam (the power of which working at full pressure is represented as one) when cut off at half stroke (that is expanded twice) the efficiency is raised by expansion 1.69+; at one-fourth stroke to 2.39+. See table of hyperbolic logarithms.

Q.—What is meant by surface condensation?

A.—A surface condenser is an instrument for condensing steam by contact with cold metallic surfaces, instead of bringing it directly into contact with a shower of cold water as done in a jet condenser. The object in using such a condenser in lieu of the common jet condenser is to furnish boilers of marine steamers with distilled instead of sea water; consequently, to provide against the loss of fuel otherwise occasioned by blowing off a portion of the water to keep the concentration at a desired point and prevent salt forming, and the loss due to the little conducting power of the envelope of scale which attaches to all heating surfaces of boilers using sea water. By the use of a surface condenser there is also gained the saving in labor and time for scaling and cleaning which belongs to all sea-going steamers using the common jet condenser; this is of no small importance to those having the care of steam boilers and machinery.

Q.—What are the principal parts of a boiler?

A.—The shell steam chest, or dome, furnace or fire-box, flues, tubes, tube plate, man-hole, mud-hole, hand-hole, feed apparatus, blow-off apparatus, sediment, collector, steam pipe, safety-valve, bars, gauges, fusible plug, steam whistle, damper, stays, and clothing.

Q.—What style of boilers are generally used for steamboats?

A.—Marine flue and tubular boilers, or cylindrical double furnace or locomotive boilers.

SPECIMEN PAPER CHIEF ENGINEER'S EXAMINATION.

Q.—What would you do if you found no water in the glass gauge or try-cocks?

A.—Draw the fires, ease safety-valve, examine tubes and combustion chambers; when boiler is sufficiently cool, pump up and proceed.

Q.—How is a feed-pump constructed, and when hot why does it not work; explain the principles on which a pump lifts water?

A.—A feed-pump consists of a cylindrical chamber fitted with a plunger, working through an air-tight stuffing box, and of a suction and a delivery valve. The lifting of the plunger forms a vacuum beneath it, the atmospheric or other pressure in the hot well then forces the water through the lower or suction valve into the pump chamber, and when the plunger returns this valve shuts, and the upper or delivery valve opens and the water is forced by the plunger into the boiler. If the pump becomes too hot, a quantity of vapour remains in the chamber and expands when the plunger rises, thus destroying the vacuum and preventing the water from entering the pump. A pump lifts water on the atmospheric principle, which is 14.7 pounds per square inch on the surface of everything.

Q.—The derangement of the check-valve will effect the pump in what manner?

A.—Should the check-valve on boiler stick fast to its seat, the pump or pipe would burst unless there be a relief valve, and if the check-valve remain open the pump would thump, and if the delivery valve were leaky, would not throw the full quantity of water.

Q.—Why should the man-hole and mud-plates be placed on the inside of a boiler?

A.—Because the pressure inside tightens the joints, and therefore makes it safest.

Q.—What is a surface blow-off? Why and when used? Where should the main blow-off be placed?

A.—The surface blow-off consists of a cock upon the boiler, with a pipe outside to the sea, and a pipe inside leading to the centre of boiler and just below the water-level. It is used to blow the scum off the water and as often as the water becomes dirty or dense. The main blow-off should be placed on or near the bottom of the boiler.

Q.—Explain the usual method of blowing scale, etc., out of boilers, etc.?

A.—Blowing-out is done by opening the surface or bottom cock on boiler, and the sea-cock on ship's side, the pressure in the boiler will force the water out as low as may be required, or altogether as the case may be. The scale is removed by scaling hammers and slices; it should be done often enough to prevent a thick scale growing on the heating surfaces, as it impairs the steaming qualities of the boiler, and also renders the furnaces and tubes liable to be burnt.

Q.—In regard to boilers, explain the danger of neglecting them; where they would decay and wear first, also their relative ages?

A.—If a boiler is not kept clean, the scale prevents the absorption of the heat by the water; the plates, therefore, may be burned and an explosion ensue. The boiler is most exposed to decay upon the bottom, or any place which is often or continually wet; it will wear most in the furnaces and along the water-line—twelve to twenty-one years in fresh water; eight to ten in salt water.

Q.—What helps to cause boiler explosions, and how are boilers chiefly injured?

A.—Boiler explosions are caused by, viz.: safety-valves being fastened down or sticking to seats; water becoming too low, and cold water imprudently pumped in upon the heated plates; an accumulation of scale, an excessive pressure. They are injured by leakage of water upon the plate from the outside. Constant leakage in seams or rivets, galvanic action from copper pipes, etc; large and sudden additions of cold water, sudden cooling by opening furnace or tube doors, and salting; these things should be guarded against by taking the precaution of preventing their occurrence; suspending zinc plates in the boiler to neutralize the galvanic action before mentioned.

Q.—What is foaming? What is priming? Is one or both dangerous? How are they controlled?

A.—Foaming is a violent ebullition or disturbance of the water; priming may be a still greater disturbance, while the water may be carried over into the engine. They are dangerous, because the gauges do not show the true water level, and the plates may be uncovered and the engine may also break down owing to the quantity of water carried into the cylinders. It may sometimes be stopped by scumming the boiler and partially closing the throttle-valve; tallow is sometimes injected for this purpose.

Q.—Why do some boilers require more watchfulness than others? Is there any danger from raising the safety-valve suddenly, and why?

A.—Some boilers require more care than others, such as locomotive or other boilers in which the quantity of water is small and the evaporation rapid, because the water would leave the glass in such a short time were the feeds to be stopped by any accident. It is dangerous to raise a safety-valve suddenly, because it may carry the water with the steam and lay bare the plates.

Q.—Describe a form of boiler that would prime badly? State what height of water should be carried over the top heating surface in a boiler?

A.—A boiler in which the tubes are placed too close to one another, or too close to the furnace crowns, or one which has too little steam space, and takes the steam from the top of the boiler instead of a dome or super-heater, it would be subject to priming. The water should be at least six inches above the top of heating surface.

Q.—What danger is there in coming to a wharf with a foaming boiler? When foaming, how do you find what water you have in boiler?

A.—There is danger in coming to a wharf with a foaming boiler, because when the engine is stopped, the water may possibly drop much further than is safe. While foaming, the water level may be found by slowing, or if necessary, stopping the engine.

Q.—In what way may the try-cocks or gauge-glass deceive you? Explain the construction and principle of gauge-glass, try-cocks, and steam gauge?

A.—The gauge-glass might deceive by being full when apparently empty, or empty when seeming to be full; or, owing to priming, the glass may show more water than there really is; or one or both cocks, etc., may be choked by dirt, salt or foam. The try-cock might deceive you from similar reasons. The glass gauge-cocks are screwed into the boiler, with the outside ends turned up and down, respectively, so as to receive the ends of the glass tube; they are placed so that both cocks being open to the boiler, the water rises to the centre of glass—there is another cock below the glass, by opening which the steam and water rush through, thus cleaning obstructions. Just opposite the openings into the boiler, a small plug is screwed, by removing which a wire may be inserted to clean out any obstructions. The Bourdon steam gauge consists of an elliptical tube, curved into an almost circular form; one end is fast and receives the steam, the other end is closed, and is connected by means of a toothed sector with a pinion and spindle which moves the pointer over the dial. The tube being curved and closed at one end, the pressure acts upon the curvative and straightens it out more or less, the pointer marking the degree of pressure.

Q.—Explain the mode of laying up an engine?

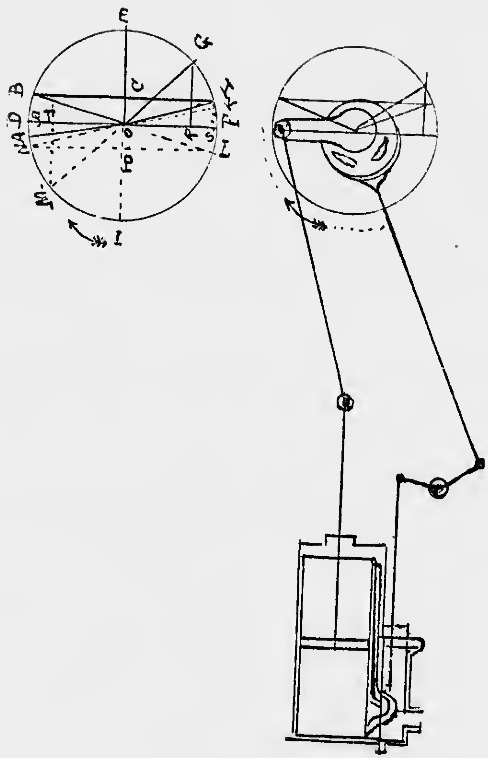
A.—When laying up an engine for the winter care must be taken that all sea-cocks are shut and the water run out of all pipes, pumps, and any places where it might lodge; the cylinders, pumps, and valve casing must be opened up, and everything well oiled; the bright work is also usually tallowed or white-leaded; in a screw steamer the coupling bolts in the shaft are taken out, that the engine may be turned by hand should the propeller be frozen in.

Q.—Explain the mode of lining an engine, and the manner of setting the eccentric ?

A.—In lining an engine, stretch a line tightly through cylinder to centre of crank pin, or if a beam engine, to centre line of beam; this will show if cylinder, guides, and beam have a common centre-line, another through air-pump to corresponding place, and another from centre of crank pin to centre line of beam; these lines must also be true to each other, which may be tested by cross lines. With a slide-valve, the eccentrics are set—the sum of lap and lead in advance of right angles to the crank, so that when the engine is on top or bottom centre the valve is open the amount of lead required.

Q.—Explain how to find if the crank pin is set true in the crank ; also if the connecting rod is hung properly?

A.—If the crank could be placed upon a true surface, the best way would be to try the centres with a surface gauge; in the steamer it can be done by placing a long straight edge lengthways on the crank pin and measuring with callipers or trammels from another straight edge or the shaft. If the connecting rod is properly hung it will come to its proper place in the centre of the crank pin.



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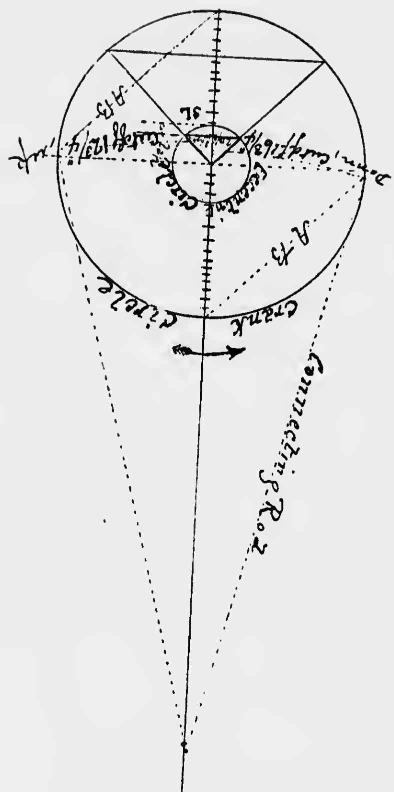

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Q.—What in mechanics is meant by the term "power?"

A.—Power is the product of pressure and motion; or the result of a certain pressure acting at a certain velocity.

Q.—What is the throw of the eccentric?

A.—Double the port and lap of valve.

Q.—How would you work an engine into port that had a broken air pump bucket and foot valve?

A.—High-pressure; if the air pump cannot be speedily repaired, and if the circulating pump cannot be used instead, and if general repairs cannot be effected, why the engine can be worked non-condensing by removing the air pump valves and exhausting through the ship's side, or if the circulating pump draws its water through the tubes, and especially if a jet is fitted, it may be done by taking the condenser's door off and removing a number of tubes and opening the jet, thus allowing the circulating pump to take away both water and condensed steam; the boiler must be fed with salt water.

Q.—What are the qualifications required for first engineer?

A.—A first class engineer shall have the qualifications of a second class engineer with not less than three years' experience on one or more steamboats of not less than 100 nominal horse-power. He must be competent to calculate the thickness of plate, pressure allowable, strength of stays, connections, joints, tensile and crushing strength of iron and steel, the capacity of the feed-pump, and of safety-valve, etc., power of engine from indicator card, make diagram of crank and eccentric, must understand steam, water, coal heat and combustion, and be competent to make working drawings of engines and boilers.

ENGINEERS' EXAMINATION FOR CERTIFICATES AND HIGHER GRADES.

Under the requirements of the "Steamboat Inspection Act, 1882," of Canada, it is necessary for every passenger steamer (or freight steamer of 150 tons) to have an engineer, graded according to the nominal horse-power, and where it is necessary to keep watch at night, it is necessary to have an assistant engineer with certificate.

Certificates of Canadian engineers are divided into four classes: "First class engineer," "Second class engineer," "Third class engineer," and "Fourth class engineer."

Examinations of engineers, exclusive of "first class," will be made at any time by the resident inspector of the district, while at the port to which the applicant belongs or by the applicant going to the inspector's office.

First class engineer must be examined by a quorum of, or full board, the chairman being present; the dates of the meetings of the board in the several districts are advertised yearly, etc., but usually have, so far, occurred in September or October, and so on to December.

Application forms may be had from any steamboat inspector by applicants that are desirous of trying for engineer's certificates, and the inspector will in return inform the applicant whether he is qualified, and for what grade; also when and where he can examine him.

It is necessary for all engineers to have recommendations from their last employers.

Candidates will be allowed five hours to work out the questions in Form No. 3.

The examination will be partly *viva voce*, and partly by examination papers and drawings.

If an engineer holds a third class certificate under the Act, 1882, he can obtain a second class engineer's certificate, if he has run a steamer of thirty nominal horse-power for two years, by making application and stating experience, without being re-examined. Fee same as an examination, five dollars.

Any engineer who has lapsed and possesses a certificate of 1882, or since, can renew and receive the same grade by making application on the correct form and paying the fee of five dollars, and proving he has not been employed on any steamer requiring a licensed engineer.

CALCULATIONS OF STAYS.

Calculate the area of a direct stay, the pitch and pressure being given. The area of a direct stay may be found by the following formula:

$$\frac{\text{Pitch}^2 \times \text{Pressure}}{6000} = \text{diam. of stay in square inches.}$$

Pitch being 8″ and pressure 100 lbs. per square inch; what is the area for a direct stay:

```
      8″ pitch
      8
      —
      64
       100 lbs. pressure per sq. inch.
      ———
6000)6400(1.066667 diam. of direct stay in sq. ins.
      6000
      ————
       40000
       36000
       —————
        40000
        36000
        —————
         40000
         36000
         —————
          40000
          36000
          —————
           40000
           42000
           —————
```

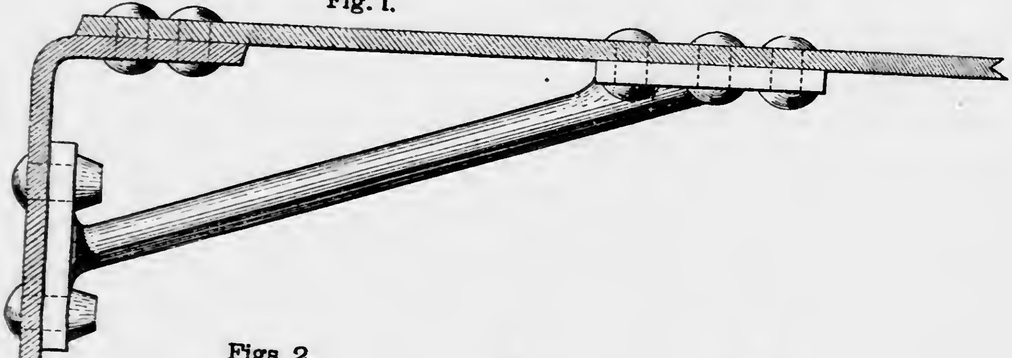


Fig. 1.

Figs. 2, & 3.

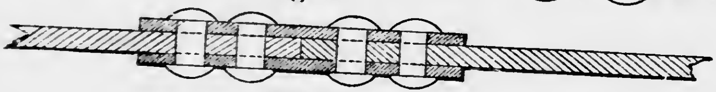


Fig. 4.

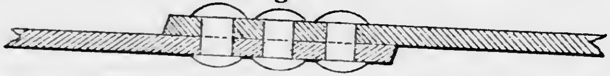


Fig. 5.

Pitch being 15″, pressure 20 lbs. per square inch; what is the area:

```
        15 inch pitch
        15
        --
        75
       15
       ---
       225
        20
       ----
6000)4500.0(.75 diam. of a direct stay in sq. inches.
     42000
     -----
      30000
      30000
      -----
```

Formula: $\frac{P^2 \times \text{Press.}}{6000} = A = \frac{\text{Pitch} \times \text{Pressure.}}{6000}$ =dia. direct [stay sq. ins.

Rule for area of direct stay:—Square the pitch and multiply by pressure per square inch, and divide by 6000, and the answer will be the diameter of a direct stay in square inches.

Calculate the strength of a direct stay of eighteen and-a-half inches pitch by fourteen inches, two inches diameter, and pressure per square inch seventy pounds.

```
   2 inches diameter direct stay.          18.5 pitch.
   2                                         14
   -                                        ----
   4 square of direct stay.                 740
.7854                                      185
-----                                      ----
   16                          Supported—2590—surface.
  20                                         70 lbs. press.
 32                                      ------
28                                       181300 lbs. actual
-----                                         [press. on stay.
3.1416 area of direct stay.
     6000 lbs. per sq. in., according to Act.
-----------
18849.6000 lbs. total pressure allowed on stay, showing
              the stay to be sufficiently strong.
```

PROOF.—Taking actual pressure on supported surface as 181300 pounds.

```
          18.5
          14
          ----740
              185
              ----
              2590
                70
              ----
        6000)181300(3.0216
              18000
              ----- .7854)3.0216(3.8485
               13000      23562
               12000      -----       3.8485(1.96 dia.
               -----       66546      1
Abbreviated    10000       62732      --
18 5×14×70÷6000 6000       -----   29)284
÷.7854=√3.8485 -----        38146     261
=1.96 or nearly 2 40000     31416     ---
in. diam. stay.   36000     ----- 286)2385
                  -----      67306    2316
                   4000      62832    ----
                             -----      69
                              44746
                              39270
                              -----
                               5476
```

PROOF.—Taking total pressure on stay, 18849.6000 lbs.

```
2″×2″×.7854×6000=18849.6000
                  6000)18849.6000(3.1416
                        18000
                        -----
                          8496
                          6000   .7854)3.1416(4
                          ----         31416
                         24960         -----
                         24000               (2″ dia. of stay.
                         -----
                          9600
                          6000
                          -----
                          36000
                          36000
                          -----
```

Then $18\frac{1}{2} \times 14 \times 70 = 181300 \div 6000 = 3.0216 \div .7854 = \sqrt{3.847}$ $= 1.96''$ diameter stay.

Then $2 \times 2 \times .7854 \times 6000 = 18849.6000 = 6000 = 3.1416 \div .7854$ $= \sqrt{4} = 2''$ diameter stay.

Calculate the strength of a direct stay nine inches pitch and fifty pounds pressure per square inch.

$$9 \times 9 = 81 \times 50 = \frac{40500}{6000} = .675 \text{ diam. in sq. inches.}$$

Calculate the area of a diagonal stay twelve feet long, line being nine, the direct stays in boiler are two inches in diameter.

The areas of diagonal stays are found in the following way: Find the area of a direct stay needed to support the surface, or if direct stays are given, compute its area, and in either case multiply the area by length of the diagonal stay, and divide the product by the length of a line drawn at right angles to the surface, supported to the end of the diagonal stay, the quotient will be the area of the diagonal stay required.

Diam. direct 2″ stay=3.1416 area of direct stay.
12 length of diagonal stay.

Line 9)37.6992

4.1888 dia. of diagonal stay in sq. ins.

```
.7854)4.1888(5.33
      39270          5.33(2.3 ins. diam. diagonal stay.
      -----          4
       26180         ---
       23562      43)133
       -----         129
        26180        ---
        23562          4
        -----
         2618
```

Calculate the area of a direct and of a diagonal stay, the distance between centres ten inches, the pressure per square inch eighty pounds; twelve feet length of diagonal stay.

```
      10
      10
     ---
     100 surface supported.
      80
     ----
6000)8000
     -----
.7854)1.3334(√1.69=1.3 diam.
       7854
       -----
       54800        ∴ 1.69(1.3″ diam. of direct
       47124          1                 stay.
       -----          -
        76760      23)69
        70686         69
        -----         --
         6074
```

```
∴      1.3334 area of the direct stay.
           12
       -------
Line 9)16.0008
       -------
       1.77786 area of a diagonal stay.
```

```
.7854)1.77786(√2.26=1.5 diam.
       15708
       -----
       20706      2.26(1.5″ dia. of diagonal
       15708      1                  stay.
       -----      -
        48980  25)126
        47124     125
        -----     ---
         1856       1
```

Abbreviated:—

$10 \times 10 \times 80 \div 6000 \div .7854 = \sqrt{1.69} = 1.3$ diam. direct stay.
$1.3334 \times 12 \div 9 \div .7854 = \sqrt{2.26} = 1.5$ diam. diagonal stay.

Or, $\dfrac{10^2 \times 80}{6000 \div 7854} = \sqrt{1.69} = 1.3$ diameter direct stay.

$\dfrac{1.3334 \times 12}{9 \div .7854} = \sqrt{2.26} = 1\frac{1}{2}$ diameter diagonal stay.

AREA OF A DIAGONAL STAY.

The following rule is given in the "S. B. Inspection Act, 1882," page 25, ss. 4th, "The area of diagonal stays are found in the following way":

"Find the area of a direct stay needed to support the surface, multiply the area by the length of the diagonal stay, and divide the product by the length of a line drawn at right angles to the surface, supported to the end of the diagonal stay required."

```
          2" diameter of a direct stay.
          2
          -
          4
         .7854
         -----
          16
         20
        32
       28
       ------
       3.1416 area of the direct stay.
            2 ft. length of diagonal stay.
Length  ------
line 1.5 ft.)6.2832(4.1888
```

Length
line 1.5 ft.)6.2832(4.1888 area of diagonal stay.

60			
28			
15	.7854)4.1888($\sqrt{5.33}$=2.3″ diam.		
	39270		
133			5.33(2.3″ diam. diag. stay.
120	26180	4	
	23562		
132		43)133	
120	26180	129	
	23562		
120		4	
120	2618		

Or 3.1416 area direct stay × 24 inches length of diagonal stay ÷ 18 inches the length of line = 1.5 feet; gives 4.1888 ÷ .7854 = $\sqrt{5.33}$; and the square root of 5.33 is 2.3, the diameter of diagonal stay.

CALCULATIONS IN BUTT-STRAP JOINTS.

Calculate the strength of double butt-strap joints, made in best manner:

$$\frac{(\text{Pitch} - \text{Diameter of rivets}) \times 100}{\text{Pitch}} = \text{Percentage of strength}$$

of plate at joints as compared with the solid plate.

$$\frac{(\text{Area of rivets} \times \text{Number of rows of rivets}) \times 100}{\text{Pitch} \times \text{thickness of plate.}} = \text{Per cent.}$$

of strength of rivets as compared with the solid plate.

When marked * the allowance may be increased still further if the workmanship or material is very doubtful, or unsatisfactory.

If the rivets are exposed to double shear multiply the percentage as found by 1.75. See "S. B. Inspection Act, 1882," page 24.

The diameter of rivets must not be less than the thickness of the plate of which the shell is made, but it will be found where the plates are thin, or when lap joints or single butt-straps are adopted, that the diameter of the rivets should be in excess of the thickness of the plates.

EXAMPLE.—Pitch $2\frac{1}{2}$ inches, $\frac{1}{2}$ in. diameter of rivets=80 %

$$\frac{(2\frac{1}{2}'' - \frac{1}{2}'') \times 100}{2\frac{1}{2}''} = 80 \text{ percentage of strength of plate at joint as}$$

compared with the solid plate.

$2\frac{1}{2}$ equals 2.5 pitch.
$\frac{1}{2}$ " .5 diameter of rivets.

2.0
100

Pitch 2.5″)200.0(80 percentage of strength of plate at
200 joints as compared with solid plate.

0

RULE.—Subtract the diameter of rivets from the pitch and multiply by 100, and divide by the pitch.

SECOND EXAMPLE.—Pitch $4\frac{1}{2}$ inches; diameter of rivets $1\frac{1}{8}$ inches:

$$\frac{(4\frac{1}{2}-1\frac{1}{8})\times 100}{4\frac{1}{2}}=\frac{(4.5-1.125)\times 100}{4.5}=75$$ per cent. of strength of plate at joints as compared with solid plate.

$$\text{Formula: } \frac{(P-t)\times 100}{P}=\text{Percentage.}$$

Calculate the percentage of the strength of rivets as compared with solid plate;—pitch $2\frac{3}{4}''$, rivets $\frac{7}{8}''$, and plate $\frac{1}{2}''$:

$$\frac{\frac{7}{8}''^2\times .7854\times 2\times 100}{2\frac{3}{4}''\times\frac{1}{2}''}=87$$ percentage of strength rivets, etc.

$$=\frac{.875\times .875\times .7854\times 2\times 100}{2.75\times .5}=87\ \%$$

$.875^2\times .7854=.6013$
2

1.2026
100

$1.75\times .5=1.375$)120.2600(874

2.75×.5=1.375)120.2600(874 percentage of strength of rivets as compared with solid plate.

```
2.75×.5=1.375)120.2600(874
              11000
              -----
              10260
               9625
              -----
                6350
                5500
                ----
                 850
```

RULE.—Area of rivets, multiplied by number of rows, multiplied by 100, divided by the sum of the pitch, multiplied by the thickness of plate.

Formula: $\frac{A \times N \times 100}{P \times t}$ = per ct. = $\frac{\text{Area} \times \text{No. rows} \times 100}{\text{Pitch} \times \text{thickness}}$ = per ct.

Then the strengths of the joints are found by the following formula: $\frac{P - D \times 100}{P}$; and $\frac{A \times or \times 100}{P \times t}$; see example.

Calculate the strength of joints and rivets as compared with the solid plate:

EXAMPLE.—Pitch 3 inches, $\frac{7}{8}$ rivets, $\frac{1}{2}$ inch thickness of plate gives 70 per cent. for joint and 80 per cent. for the rivets.

$$\frac{(3 - .875) \times 100}{3} = 70\ \% \qquad \frac{.6013 \times 2 \times 100}{3 \times .5} = 80\ \%$$

```
Pitch 3"
   .875 thickness plate
   ----
3)2.125
   ----
     70 percentage of strength of plate at joint as compared with solid plate.
```

```
7/8=.875²×.7854=.6013 area riv.
                   2 rows.
                ------
                1.2026
                   100
                ------
Pitch t.
3 × .5=1.5)120.2600(80.1 % of stgth riv'ts as comp'd sol. plte
           120
           ---
            26
            15
            --
            11
```

The lowest percentage is taken for strength of joint.

Calculate the strength of double butt-strap joints, made in best manner:

With $2\frac{1}{2}$ inch pitch, $\frac{7}{8}$ inch rivets, and $\frac{1}{2}$ inch plate; what would the strength of plate be at the joint, also strength of rivets, as compared with solid plate:

```
2½"=2.5 inches pitch of rivets.
     .875 diameter of rivets.
    -----
    1.625
       100
    ------
2.5)162.500(65  percentage of strength of plate at
    150         joint as compared with solid plate.
    ---
     125
     125
     ---
```

```
7/8=.875 × .875 × .7854=.6013 area of rivet.
                            2 number of rows.
                       ------
                       1.2026
         2.5               100
          .5           -------
         ---1.25)120.2600(96.2 percentage of rivets
                 1125            compared solid plate.
                 ----
                  776
                  750
                  ---
                   260
                   265
                   --
```

But according to the Steamboat Inspection Act, 1882, joints must be 70, and rivet over 70 percentage of the plate, so 3 inch pitch $\frac{1}{2}$ plate, $\frac{7}{8}$ inch rivets, will give 70 and 80 per cent. respectively, as the following worked out example will show:

```
                          .6013 area of 7/8 rivet.
      3.                      2 number of rows.
       .875                -------
      -----          3    1.2026
      2.125           .5      100
          100        ---  ---------
      --------     1.5)120.2600(80.1734 % strength rivets.
    3)2.12500           120
     ---------          ----
      70.834%strength     26
          of joints.      15
                          ---
                          110
                          105
                          ---
                           50
                           45
                           ---
                            50
                            60
                            ---
```

$$\frac{3-.875\times 100}{3}=70\,\%$$

$$\frac{.6013\times 2\times 100}{3\times .5}=80.1734\,\%\text{ rivets.}$$

Pitch being $3\frac{3}{4}$ inches, rivet $1\frac{1}{8}$, thickness of plate $\frac{3}{4}$ of an inch; calculate the strength of plate at joint and rivets as compared with the solid plate:

$$\frac{3.75-1.125\times 100}{3.75}=\text{pitch}$$

```
        3.75 pitch.
        1.125 rivets.
        -----
        2.625
           100
        -------
  3.75)262.500(70.0 percentage strength
       2625          joint compared solid plate.
       ------
       000000
```

$$\frac{1\frac{1}{8} \times 1\frac{1}{8} \times .7854 \times 2 \times 100}{3.75 \times .75} = 71$$ percentage strength of rivets.

1.125 ² × .7854 = .9940(70.06 percentage strength of rivets comp'd solid plate.

```
 Pitch              2
 3.75             -----
  .75 thickness   1.9880
 ----                100
 1875             --------
2625              198.8000
 ---              196875
 ?5               --------
                   192500
 ?.5)1'            169750
                   -------
                    22850
```

In a double-rivetted seam the rivets are $1\frac{1}{8}''$ diameter, and placed at $4\frac{1}{2}$ pitch; plate 1″ thick; what percentage of strength has joint compared with the solid plate and rivets, etc., rivets being exposed to double shear.

$$\frac{4\frac{1}{2}—1\frac{1}{8} \times 100}{4\frac{1}{2}} = 75\ \% = \frac{4.5—1.125 \times 100}{4.5} = 75\ \%$$

```
   4.5
   1.125
   -----
   3.375
     100
   -------
45)337.500(75  percentage of strength of plate at
   315         joint as compared with solid plate.
   ---
    225
    225
    --
```

```
1⅛ × .7854 = .9940
                  2
             ------
             19880
        4.5       100
        --- ---------
        4.5)198.8000(44.18×1.75=77 percentage of
             180                    strength of rivets
             ---                    as compared with
              188                   solid plate.
              180
              ---
                80
                45
                --
               350
               350
               ---
```

If the rivets are exposed to double shear × 1.75.

In a double rivetted seam, the rivets are $1\frac{1}{4}$ inch diameter, and placed at four inch pitch; plate one inch thick; what percentage of strength has the plate at the joints, and rivets as compared with the strength of solid plate:

$$\frac{4-4\frac{1}{4}\times 100}{4}=68\%=\frac{4-4.25\times 100}{4}=68\%=$$

```
  4.00
  1.25
  ----
4)275(68.7 percent.
  24     strength of
  --     plate at j'ts.
   35    compared
   32    with solid
   --    plate.
    30
    28
    --
     2
```

$$\frac{1\frac{1}{4}\times 1\frac{1}{4}\times .7854\times 2\times 100}{4\times 1}=61\%\text{ strength rivets.}$$

In a treble rivetted seam the rivets are $1\frac{1}{8}$ inch diameter, and placed at $4\frac{1}{8}$ inch pitch; plate one inch thick; what percentage of strength has the joint compared with the solid plate:

```
                          4.125" pitch.
                          1.125
                          ------
                   4.125)3.0000(72.7 °/o of strength of
                          28875          plate at joints as
                          -----          compared with
                          11250          solid plate.
4.125—1.125×100            8250
--------------- = 72°/o   -----
     4.125                 30000
                           28955
                           -----
                            1045

1.125×1.125 × .7854=.9940
                        3
                    -----
                    29820
                      100
                    -----
4.125 × 1 = 4.125)2982000(72.29 percentage strength of
                   28875        rivets as compared with
                   -----        solid plate.
                    9450
                    8250
                    -----
                    12000
                     8250
                    -----
                     37500
                     37125
                     -----
                       375
```

For formula of rules for strength of joints, etc., see "Steamboat Inspection Act, 1882," in the "rules and regulations" for boiler; page 24 of official issue of the Act.

Calculate the percentage of strength of rivets as compared with solid plate, rivets being $\frac{5}{8}''$ of two rows, pitched $2\frac{1}{12}''$ and plate of $\frac{3}{8}''$ thick.

$$\frac{d \times n \times 100}{p \times t} = \text{Percentage of strength of rivets, etc.}$$

d=area of rivets.
n=number of rows of rivets.
p=pitch.
t=thickness of plate.

```
 5/8"=.625 diameter of rivet.
      .625
      ----
      3125
     1250
    3750
    ------
   .390625
     .7854
   -------
   1562500
  1953125
 3125000
2734375
----------
.3067968750 area of rivet.
          2 number of rows.
-----------
.6135937500
        100
------------
2.083 + × .375=.78)61.35937500000(78.666 percent. strength of rivets as compared with solid plate.
                   546
                   ---
                    675
                    624
                    ---
                     519
                     468
                     ---
                      513
                      468
                      ---
                       457
                       468
                       ---
```

Or $\dfrac{2\frac{1}{12}-\frac{5}{8}}{2\frac{1}{12}}\times 100=70\ \%=\dfrac{\frac{25}{12}-\frac{5}{8}}{\frac{25}{12}}\times 100=.70\ \%$ strength of plate at joints, etc.

$2\frac{1}{12}-\frac{5}{8}=\frac{25}{12}-\frac{5}{8}=\frac{50}{24}-\frac{15}{24}=\frac{35}{24}\div\frac{25}{12}=\frac{7}{10}=.70\ \%$

$\dfrac{\frac{5}{8}\times\frac{5}{8}\times .7854\times 2\times 100}{2.083+,\times .375}=78\ \%$ strength of rivets, etc.

Or $\dfrac{\frac{5}{8}^2\times .7854\times 2\times 100}{2\frac{1}{12}\times\frac{3}{8}}=78\ \%$

Or $\dfrac{.625\times .625\times .7854\times 2\times 100}{2.083334\times .375}=78\ \%$ strength rivets, etc.

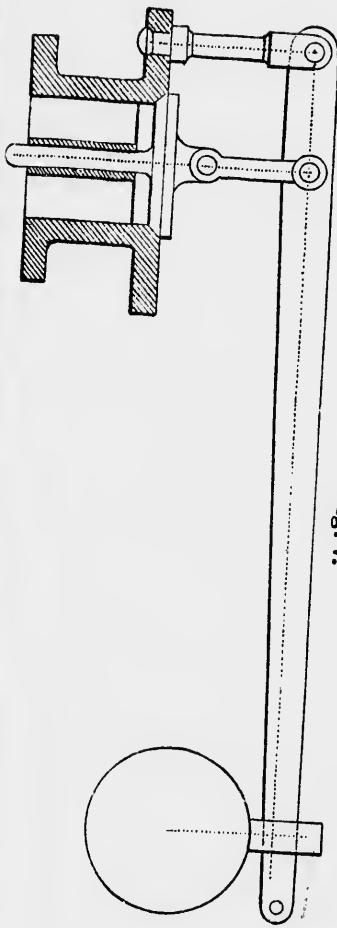


Fig. 7.

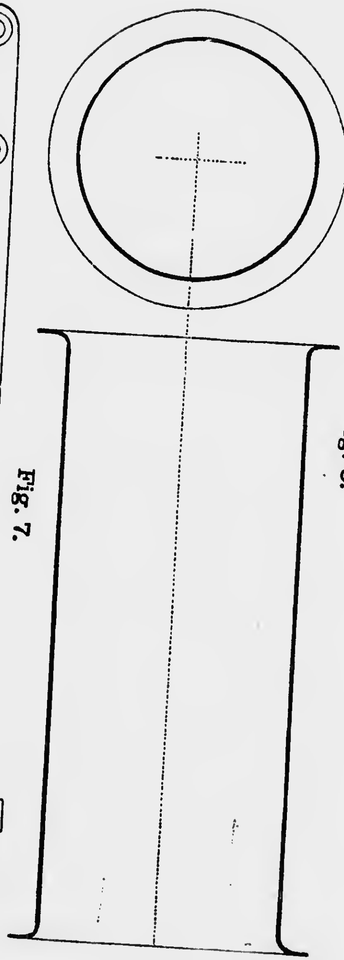


Fig. 6.

CALCULATIONS ON SAFETY-VALVES.

Calculate the area of a safety-valve, *vide* section 20, page 10, "Steamboat Inspection Act, 1882."

"The area of any locked safety-valve, or the joint areas of any locked safety-valves to any boiler, made or placed on board after the passing of this Act, shall not be less than half a square inch for each square foot of grate surface in or under the boiler.... The boiler, or each boiler, if more than one, of every steamboat, be provided with two safety-valves, one of which shall be locked up and one open."

Rule for area of safety-valve:—Half a square inch of safety-valve area to every square foot of grate surface.

Formula: $\frac{G\ S}{2} = A$; or $G\ S \times .5 =$ area.

Rule: $\frac{\text{Grate surface in sq. feet.}}{2} =$ area in square inches.

What should be the area of a safety-valve for a boiler with 23.6 square feet of grate surface:

2)23.6 square feet, GS.

11.8 square inches, area of safety-valve.

Or—

$$\begin{array}{r} 23.6 \\ .5 \\ \hline 11.80 \end{array}$$

11.80 square inches area of safety-valve.

Abbreviated: $\frac{23.6 \text{ area.}}{2}$=11.8; or 23.6×.5=11.8 sq. ins. area.

What would the area of the safety-valve be for a boiler with twenty-six square feet of grate surface:

2)26 square feet of grate surface.

13 square inches area of safety-valve.
Or, 26×.5=13.0 square inches area of safety-valve.

Compute the area of a safety-valve for a boiler with twenty-four square feet of grate surface.

RULE.—One-half ($\frac{1}{2}''$) square inch of area for every square foot of grate surface.

$$\frac{GS}{2} = A., \text{ means } \frac{\text{Grate surface.}}{2} = \text{area.}$$

∴ 2)24

12 square inches area of safety-valve.

Abbreviated:—

24÷2=12 square inches area of safety-valve.
Or, $\frac{24}{2}$= " " "
Or, 24×.5= " " "

Area means area of safety-valve in inches.
S V. " safety-valve.
∴ " then.
= " equals.

The rule for area of safety-valve is the same as the British Board of Trade rule.

Calculate the weight required for the safety-valve, size of the fulcrum lever, etc., being given, and the boiler pressure per square inch:

RULE.—Multiply the square of the diameter of safety-valve by .7854; then multiply this sum by the pressure on boiler per square inch; subtract the effective or dead weight of the parts; then multiply this product by the fulcrum, and divide by the length of lever, equals the weight in pounds for the ball required for end of lever.

$$\text{Formula: } \frac{D^2 \times .7854 \times P - DW \times F}{L} = W.$$

D^2=Diameter of valve multiplied by itself.

P=Pressure per square inch on boiler.

DW=Dead weight or effective weight of parts.

F=Fulcrum in inches.

L=Lever in inches.

.7854=One circular or decimal inch used to get area of valve.

×=Sign of multiplication.

—=Sign of subtraction.

=means equals.

Example.—Diameter of valve being four inches, boiler pressure forty pounds per square inch, dead weight of parts (lever, valve, spindle, etc.,) fifty-two pounds, fulcrum five inches, and lever forty-five inches long; the required weight of the ball would be 116.88 pounds, or a little over 116¾ pounds.

4 inches diameter of valve.
4
—
16 inches sq. of valve.

16 ins. sq. of value.
.7854
———
64
80
128
112
————
12.5664 area of valve.
40
————
402.6560 lbs. total press. on valve.
52
————
350.6560 lbs. actual pressure.

350.6560 lbs. actual pressure.
5 ins. fulcrum.
————
15)1753.2800(116.8853+lbs. weight.
15
—
25
15
—
103
90
—
132
120
—
128
120
—
80
75
—
50
45
—

Calculate the weight required at the end of a lever twenty-one inches long, four inches fulcrum, five inches diameter of valve, twenty-five pounds pressure per square inch, effective weight of lever, etc., ninety pounds.

5 inches diameter of valve.
5
—
25 square inches.
.7854
———
100
125
200
175
————
19.6350

```
        19.6350 area of safety-valve.
             25 lbs. pressure per sq. inch on boiler.
        -------
         981750
        392700
        -------
       490.8750 lbs. press. per sq. in. on safety-valve.
        90
       --------
       400.8750 lbs. actual press. per sq. in. on safety-valve.
             4 inches fulcrum.
       --------
(Lever 21 inches)16035000(76.357143, or 76⅓ lbs. weight.
                 147
                 ---
                 133
                 126
                 ---
                   75
                   63
                   ---
                   120
                   105
                   ---
                    150
                    147
                    ---
                      30
                      21
                      --
                      90
                      84
                      --
                      60
                      63
                      --
```

Abbreviated—

$$\frac{5 \times 5 \times .7854 \times 25 - 90 \times 4}{21} = 76\tfrac{1}{3} \text{ lbs. weight.}$$

SHORT RULE.—Area of valve multiplied by the pressure per square inch, multiplied by the fulcrum; divide by the lever in inches will give you a rough estimate of the weight required.

Formula: $$(d^2 \times .7854)\ \frac{A \times P \times F}{L} = W$$

To find the weight on the end of a lever:

Let P=Power.
W=Weight.
S=Short arm.
L=Long arm.

Short arm is the distance a....b.
Long arm is the distance a....c.

Then
$P \times S \div L = W$
$W \times L \div S = P$
$S \times P \div W = L$
$L \times W \div P = S$

Power is area of valve multiplied by steam pressure.
Area of valve is found by multiplying sq. of its diam. by decimal .7854.

EXAMPLE.—Diameter of valve three inches; pressure of steam twenty pounds per square inch; length of short arm (a....b) three inches; length of long arm (a....c) is thirty inches.

3 inches diameter of valve.
3
—
9 inches square of diameter of valve.
.7854
9
———
7.0686 area of valve.
20 lbs. pressure per square inch.
———
141.3720 lbs. total pressure on valve.
4
———
137.3720 lbs. actual pressure on valve.
3 inches fulcrum.
———
412.1160

Long arm=30")412.1160(13.74, or $13\frac{3}{4}$ pounds weight.

```
30
---
112
 90
---
 221
 210
 ---
  110
  120
  ---
```

Abbreviated: $3\times3\times.7854\times20-4\times3\div30=13\frac{3}{4}$ lbs. weight.

CALCULATIONS IN PUMPS.

The arithmetical examination of candidates for licenses as engineers, by the Board of Steamboat Inspection of the Dominion of Canada, consists of ten questions; two in relation to the feed-pump, one as an example of multiplication of decimals, two questions on boilers, involving the thickness of plate required for the pressure allowed, two relating to the safety-valve, its area and weight required at end of lever, etc.; the remaining sums are the horse-power of an engine and butt-strap joints.

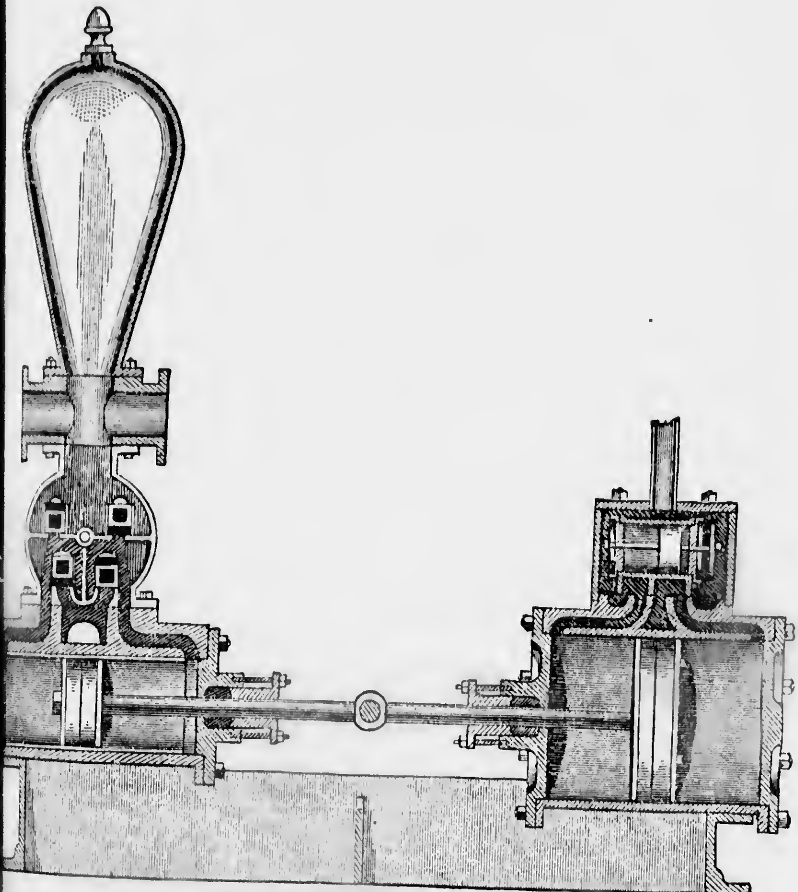
I would advise the engineer student to learn these rules, so as to have complete knowledge of them, and work out every example, because these questions are requisite to pass the Board, and a complete and correct understanding of them is required of every engineer.

Previous to entering into a examination it would be advisable for the candidate to review his knowledge of the first four rules of arithmetic, decimal fractions and proportion, as it is the very best preliminary exercise he can take for to successfully assist him in understanding and working correctly any calculations that may be assigned him; also it would be desirable for him to study the rules of formula and signs as used in arithmetic, for fear that he may have forgotten these things from disuse, or their being crowded out of his mind by the more important every-day facts and difficulties of his calling.

Ques.—Calculate the contents of a feed-pump?

Ans.—This question consists in getting the cubic contents of the pump, therefore the following rule may be devolved:

RULE.—Compute area of diameter of pump, and multiply this product by stroke in inches; or, in other words, square



No. 5. SCALE 1 in 1 FOOT.

SECTIONAL DIRECT-ACTING PUMP.

Page 214.

d
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diameter of pump, (that is, multiply the diameter by itself), then multiply by .7854, and multiply this product by the stroke in inches.

Formula:—$d^2 \times .7854 \times S = CP$.

EXAMPLE.—Calculate the contents of feed-pump, the diameter being four inches and stroke ten inches.

4 inches diameter feed-pump.
4
—
16 square diameter of feed-pump.
.7854 decimal or circular inch.
16
———
47124
7854
————
12.5664 area of feed-pump.
10 inches stroke of feed-pump.
————
125.6640 cubic ins. contents of feed-pump.

Abbreviated as for the examination paper:

$4'' \times 4'' \times .7854 \times 10'' = 125''$ .6640 cubic inches contents of the feed-pump.

SECOND EXAMPLE.—In "contents of the feed-pump," diameter of the feed-pump being three and-a-half inches, and stroke of feed-pump five and-a-half inches; what is the contents?

$3\frac{1}{2}'' = 3.5$ inches diameter of feed-pump.
3.5
——
175
105
———
12.25

```
      12.25 square of diameter of feed-pump.
      .7854 circular inches.
      -----
       4900
      6125
     9800
    8575
    -------
    9.621150 area of the feed-pump.
         5 5
    --------
   48105750
  48105750
  ----------
  52.9163250 cubic ins. contents of feed-pump.
```

Abbreviated—$3.5^2 \times .7854 \times 5.5 = 52.916325$
Or, $3\frac{1}{2}^2 \times .7854 \times 5\frac{1}{2} = 52\frac{15}{16}$.

THIRD EXAMPLE.—Two and-a-half inches diameter of feed-pump, five and three-quarter stroke.

```
    2.5
    2.5
    ---
   125
   50
   ---
   6.25
  .7854
  -----
   2500
  3125
 5000
4375
--------
4.908750
```

```
    4.908750
        5.75
   ---------
   24543750
  34561250
 24543750
 -----------
 28.22531250 cubic ins. contents of feed-pump.
```

FOURTH EXAMPLE.—Feed-pump of five inches diameter and fourteen inches stroke.

```
 5
 5
--
25
```

25
.7854

100
125
200
175

19.6350
14

785400
196350

274.8900 contents of feed-pump.

Fifth Example.—Calculate the contents of a feed-pump $4\frac{7}{8}''$ diameter and $8\frac{3}{8}''$ stroke.

$4\frac{7}{8}$ $(7 \div 8 = .875) = 4.875$
4.875

24375
34125
39000
19500

23.765625
.7854

95062500
118828125
190125000
166356375

18.6652218750
8.475

933261093750
1306565531250
746608875000
1493217750000

158.1877553906250 contents of feed-pump.

Examples of feed-pump sum to be worked out:

Diameter of feed-pump.	Stroke.	Contents.
$4\frac{1}{4}$ = (4.25)	$6\frac{1}{2}$ = (6.5) =	103.382750
$4\frac{1}{2}$ = (4.5)	$7\frac{3}{4}$ = (7.75) =	123.25871250
$4\frac{7}{8}$ = (4.875)	$8\frac{3}{8}$ =(8.475)=	157.131276
5	14 =	274.8900
6	18	508.9392
6	10	282.744

SIZE PUMP REQUIRED.

To calculate the size pump required from the dimensions of the boiler, is a question that engages to do a good deal, and can only truly be correctly arrived at by practice, trial, and supposition, from examples in use.

The following rules or methods are given as ways to arrive at the approximate data for size; the best plan is to calculate the evaporating power of the boiler and to proportion a pump over and sufficient to supply the water used by the boiler per hour. The following rules are based on either the quantity of steam used by the engine, or the water evaporated by a boiler of given dimensions per hour.

These rules, tempered with practice and experience, may be found useful.

Calculate the size pump supplying water to a boiler, supplying an engine with cylinder thirty inches diameter, stroke eight feet, making twenty-five revolutions per minute, cutting off at half stroke, pressure thirty pounds per square inch.

In answering this question, we shall assume that the steam is always cut off at one-half the stroke; if the amount of cut off is variable the feed-pump should be proportioned to suit the largest requirement of the engine.

30
30
——
900 square of cylinder × .7854=706.86 sectional area of cylinder in square inches. Since the steam is cut off at

half stroke, engine uses steam in one revolution equal to the capacity of the cylinder, then 706.86

```
             706.86
                 96 inches=8 ft.×12 ins.
             ------
             424116
            636174
            -------
           67858.56 cubic inches of steam
```

used per revolution. At a temperature of 30° above the atmosphere, the specific volume of steam is 608, then

```
608)67858.56(111.6 or nearly 112 cubic inches of
    608               water used in each revolution.
    ---
     705
     608
     ---
      978
      608
     ----
     3705
     3648
     ----
       57
```

But provision must be made for loss of and by defective action of valves, clearance in steam cylinder, leakage, priming and brining; so that capacity of pump should be about three-and-a-half times the amount of water theoretically used in this case.

```
 112 cubic inches of water.
 3.5
 ---
 560
336
----
392.0 cubic inches of water per revolution, the
              required capacity of pump.
```

Suppose it to be a beam engine with the pump connected to beam at a point giving it half the stroke of the piston, then

```
48)392(8.16
   384
   ---
    80
    48
    ---
    320
    288
    ---
     32
```

```
.7854)8.166666(10.3981
       7854
       -----
       31266
       23562
       -----
        77046
        70686
        -----
         63606
         62832
         -----
           7740
           7854
           ----
```

```
10.3981(3.22 diameter.
 9
 --
62)139
   124
   ---
642)1581
    1284
    ----
     297
```

So a pump three and-a-quarter inches diameter, four feet stroke, single acting, would be the proper size for this engine.

Calculate the size pump for a boiler of given dimensions. A boiler eleven feet in diameter, containing two furnaces each, length of grate five and-a-half feet by three feet, pump two-thirds full each stroke.

```
 5.5
  .3
----
16.5
   2
----
33.0
```

33.0 square feet grate surface.
20

660.0 coal burnt per hour.
10

Weight
cubic ic.=62.5)6600.0 lbs. water evaporated per hour.

And that equals 105.6 cubic feet; assuming the pump to be two-thirds full each stroke; and to be capable of throwing twice the quantity of water evaporated to allow for leakage, blowing off, etc., the capacity of pump per hour will be

105.6
2

3)211.2

60)70.4=⅔ full each stroke.
2

60)140.8=double capacity.

80)2.3466

.02933
2 for leakage, etc.

.05866
1728

46928
11732
41062
5866

10)101.36448

.7854)10.136448

12.90(3.6 diameter of pump.
9

66)390
396

Then: answer is,
3.6 ins. diameter.
10″ stroke.
80 revolutions.

CALCULATE THE SIZE PUMP REQUIRED.

Calculate the size pump for a boiler with three furnaces 3 feet by 5 feet, allowing the consumption of coal to be 15 pounds per square foot of grate surface per hour.

```
                  45 square feet of grate surface.
                  15
                 ---
                 225
                 45
                 ---
                 675 lbs. burnt per hour.
                   10 lbs. water = 1 lb. of coal.
                 ----
1 cubic ft.=62.5)6750 lbs. water evaporated per hour.
                 ----
               60)108 cubic feet per hour.
                 ----
                 70)1.8 cubic feet per minute.
                    -----
                    .0257 cubic feet per revolution.
                    .1728
                    -----
                     2056
                     514
                   1799
                   257
                  -------
                  44.4096 cubic inches per revolution.
                        2
                  -------
                  88.8192 double capacity for leakage.
                        2
Supposed stroke  --------
    of pump=14)177.6384 double again for leakage of boiler,
                 -------            pump gear, etc.
          .7854)12.6884
                -------
              √16 15(4.09 diameter of pump.
               16
              -----
             89)1500
                 1521
                 ----
```

Size pump 4″ diameter, 14″ stroke and 70 revolutions, cut off at half stroke but double capacity taken; so this does not occur in this calculation, that is, the multiplying by 1 and dividing by 2; assuming the pump to be only half full each stroke and therefore allow for a capacity of twice that quantity per revolution which brings it to 88.8192 cubic inches, allowance has still to be made for a leaky boiler and pump gear and the additional quantity of water often necessary; and therefore, to be safe, again increase the capacity to $88.8192 \times 2 = 177.6384$ cubic inches per revolution.

Assuming again a single acting pump making a stroke of say 14 inches, then $177.6384 \div 14 = 12.6884$ square inches area of pump $\div .7854 = \sqrt{16.15} = 4.09$ inches diameter of pump, 70 revolutions, 14 inches stroke.

This is the method usually employed by candidates in working the examination question No. 11, Part II. It has therefore been worked out continuously without written explanation and is so added to follow this discription of the rule which the student will please see work in examination paper accordingly.

Calculate the size pump for a boiler of a given dimension.

Given a boiler say 12 feet diameter, containing three furnaces three feet, width of fire bars five feet; the grate surface of a boiler would be $3' \times 5' \times 3' = 45$ square feet, allowing the consumption of coal to be 15 pounds per square foot grate surface per hour.

```
  45
  15
 ———
 225
 45
 ———
 675 pounds coal burnt per hour.
```

Allowing the high evaporative power of 10 pounds of water for one pound of coal, $675 \times 10 = 6750$ pounds water evaporated per hour, divided by 62.5 pounds per cubic foot=62.5)6750.0(108 cubic feet per hour.

```
       625
      ————
       5000
       5000
      ————
```

∴ 60)108 cubic feet per hour.

Revolutions 70)1.8 cubic feet water per minute.

.0275 cubic feet per revolution.
1728

2056
514
1799
257

44.4096 cubic inches per revolution.

Owing to leakage, stuffing boxes and vapour arising from feed water, then increase the capacity to 88.8192 for the leakage, etc., and double this again for leakage of boiler, defective pump gear and necessary water required for other uses, etc., which will give us 177.6384, then dividing this by 14, the supposed stroke of pump and by .7854, we get 16.15″, and the square root of this is 4.09″, the diameter of pump.

HEATING SURFACE OF MARINE BOILERS.

Ratio of heating surface, 35 square feet to one of grate surface.

Area through tubes $\frac{1}{4}$ to $\frac{1}{6}$ of grate surface.
Steam room $\frac{1}{2}$ of water room.
Funnel area $\frac{1}{8}$ of grate surface multiplied by
Heating surface=pounds of coal per hour multiplied by 1.3 heating surface per nominal horse-power=16 square feet.
Heating surface to be taken into account.
Top of flues ($\frac{1}{2}$), side back and top of back connection (flame box), back tube plate and tubes:—weight of boilers multiplied by the surface plates per foot and by the thickness in inches and ÷ 20 = weight in cwts.

$$\frac{\text{Surface in square feet} \times \text{eights}}{20} = \text{Weight in cwts.}$$

TABLE OF VALUE OF ADDED FRACTION=DECIMALS.

Fractions.	Decimal value.	Fractions.	Decimal value.
$\frac{7}{8}+\frac{3}{32}$	.96875	$\frac{5}{8}+\frac{1}{16}$	.6875
$\frac{7}{8}+\frac{1}{16}$	.9375	$\frac{5}{8}+\frac{1}{32}$	.65625
$\frac{7}{8}+\frac{1}{32}$	.90625	$\frac{5}{8}$	.625
$\frac{7}{8}$	.875	$\frac{1}{2}+\frac{3}{32}$	.59375
$\frac{3}{4}+\frac{3}{32}$	.84375	$\frac{1}{2}+\frac{1}{16}$	.5625
$\frac{3}{4}+\frac{1}{16}$	.8125	$\frac{1}{2}+\frac{1}{32}$	.53125
$\frac{3}{4}+\frac{1}{32}$	.78125	$\frac{1}{2}$	.5
$\frac{3}{4}$	.75	$\frac{3}{4}$	.75
$\frac{5}{8}+\frac{3}{32}$	.71857	$\frac{1}{4}$	.25

HORSE-POWER SUMS.

CALCULATE THE HORSE-POWER OF A STEAM ENGINE.

A horse-power is equal to 33000 pounds lifted one foot high in one minute, therefore the horse-power of an engine will be the area of the cylinder multiplied by pressure per square inch multiplied by the speed of piston in feet per minute divided by 33000.

EXAMPLE.—Diameter of cylinder forty inches, stroke of piston ten feet, twenty revolutions per minute, pressure of steam per square inch, as per gauge, thirty pounds; vacuum twenty-six inches, as per mercury gauge. Calculate the horse-power of this engine.

```
         40 inches diameter of cylinder.
         40
        ----
       1600 square of the cylinder.
      .7854
      -----
       6400
      8000
    12800
   11200
   --------
   1256.6400 area of cylinder in square inches.
          43 pounds steam pressure.
   ---------
    37699200
   50265600
   ---------
   54035.5200 pressure per square inch in cylinder.
          400 speed of piston per minute.
   ------------
  21614208.0000
```

```
33000)21614208 0000(654.976, or 655 horse-power.
      198000
      ------
       181420
       165000
       ------
        164208
        132000
        ------
         322080
         297000
         ------
          250800
          231000
          ------
           198000
           198000
           ------
```

Abbreviated—

$$\frac{40^2 \times .7854 \times 43\ (30+13) \times 400\ (10 \times 2 \times 20)}{33000} = 655 \text{ horse-power.}$$

Calculate the horse-power of an engine, the diameter of the cylinder being 10 inches, 4 feet stroke, 45 revolutions per minute, pressure of steam 60 pounds per square inch:

```
      10 inches diameter of cylinder.
      10
     ---
     100 square of the cylinder.
   .7854
   -----
     400
    500
   800
  700
  -------
 78.5400 area of cylinder in square inches.
      45 revolutions per minute.
 -------
392.7000
3141600
--------
3534 3000
```

```
               3534.3000
                       2
               ---------
               7068.6000
                       4 stroke.
              ----------
              282744000
                     74 lbs. pressure.
             ----------
             1130976000
            1979208000
            -----------
      33000)20923056000(63.4032 or 63½ horse-power.
            198000
            ------
            112305
             99000
            ------
             133056
             132000
             ------
              105600
               99000
              ------
                66000
                66000
                -----
```

Second method, using constant multiplier .0000238.

```
        10                    36000
        10                       74
        ---                  ------
       100                   144000
         4                  252000
       ---                  -------
       400                  2664000
        45                .0000238
      ----                ---------
      2000                 21312000
     1600                  7992
     -----                5328
     18000                -----------
         2                63.4032000 horse-power.
     -----
     36000
```

A short method for calculating the horse-power of an engine:

The short rule for the horse-power of an engine; (of an engine, 5 feet 10 inches being diameter of cylinder, 6 feet stroke, 15 revolutions per minute, 25 pounds pressure per square inch): Square diameter of cylinder, multiply by stroke in feet, double revolutions and the pressure, and by the constant multiplier, .0000238 which is .0000238=(.7854 ÷33000). Then

```
       70 diameter of cylinder in inches.
       70
     ----
     4900
        6 stroke in feet.
    -----
    29400
       30 double revolution.
   ------
   882000
       25 lbs. pressure per square inch.
  -------
  4410000
 1764000
 --------
 22050000
 .0000238      constant multiplier.
 --------
  176400000
  6615
 4410
 -----------
 524.7900000 or 524¾ horse-power of the engine.
```

Formula: $D^2 \times S \times 2R \times P \times C$.

D^2=Square the diameter of cylinder.

S=Stroke in feet.

2R=Double revolutions.

P=Total pressure per square inch in pounds.

C=Constant multiplier for horse-power which is .0000238.

```
33000).7854000(.0000238 constant multiplier.
       66000
       ------
       125400
        99000
       ------
        264000
        264000
        ------
```

Calculate the horse-power of an engine forty inches diameter of cylinder, eight feet stroke, twenty revolutions per minute, forty-two pounds pressure per square inch.

```
            40 inches diameter of cylinder.
            40
           ----
          1600 square of cylinder in inches.
             8 feet stroke.
         -----
         12800
            40 double revolutions per minute.
        ------
        512000
            42 lbs. pressure per square inch.
       -------
       1024000
      2048000
     --------
      21504000
     .0000238   constant multiplier.
     ---------
     172032000
     64512
    43008
    -------------
    511.7952000 or 511¾ horse-power.
```

```
Old method:  40 inches diameter of cylinder.
             40
             --
           1600
          .7854
          -----
           6400
          8000
        12800
       11200
      ---------
      1256.6400 area of cylinder.
              8 feet stroke.
      ---------
      100531200
             42
      ---------
      201062400
     402124800
     ----------
     4222310400
             40
     ----------
33000)16889241.6000(511.7952, or 511¾ horse-power.
      165000
      ------
       38924
       33000
       -----
        59241
        33000
        -----
        262416
        231000
        ------
         314160
         297000
         ------
          171600
          165000
          ------
            66000
            66000
            -----
```

Calculate the horse-power of a compound engine; the diameter of the high pressure cylinder fifty-nine inches, stroke forty-eight inches, mean pressure 33.3 pounds per square inch, and 53.7 revolutions per minute; low pressure cylinder 10.7 inches diameter, and 12.75 pounds mean pressure per square inch, forty-eight inches stroke.

		I. H. P.
HP.,	59 × 59 × .7854 × 33.3 × 8 × 53.7 ÷ 33000 =	1185
LP.,	107 × 107 × .7854 × 12.75 × 53.7 × 8 ÷ 33000 =	1492
	Total indicated horse-power	2684

Calculate the horse-power of an engine forty inches diameter of cylinder, ten feet stroke, twenty revolutions per minute, twenty-five pounds steam pressure, and thirteen pounds vacuum.

$$40 \times 40 \times .7854 \times 38 \times 10 \times 2 \times 20 \div 33000 = 578 \text{ horse-power.}$$

Rule for calculating horse-power of an engine: Square the diameter of the cylinder in inches, and get its area by multiplying this square by .7854, then multiply the area by the stroke in feet, the pressure, and double the revolutions, and divide by 33000.

Short rule, using constant .0000238. Square the diameter of cylinder in inches, multiply this by stroke in feet, double the revolutions, and the pressure per square inch, in pounds, and by the constant .0000238.

Formula: $D^2 \times S \times 2R \times P \times C = \text{horse-power.}$

Calculate the mean pressure of an engine 107 inches diameter of cylinder, 12.75 pounds mean pressure per square inch, 53.7 revolutions per minute, four feet stroke.

```
  107 inches diameter of cylinder.
  107
  ---
  749
 1070
 ----
11449
```

```
          11449 square of cylinder.
          .7854
          -----
          45796
         57245
        91592
       80143
       --------
       89920446 area of cylinder.
           12.75 lbs. mean pressure per square inch.
       ----------
      449602230
     629443122
    179840892
    89920446
    --------------
    114648.568650
              53.7 revolutions per minute.
    ----------------
    802539980550
   343945705950
  573242843250
  ----------------
  6156628.1364050
                8 feet stroke.
  ----------------
33000)49253025.0912400(1492.516 or 1492½ horse-power.
      33000
      ------
      162530
      132000
      ------
       305302
       297000
       ------
         83025
         66000
        ------
        170250
        165000
        ------
          52500
          33000
          ------
          195000
          198000
          ------
```

$$\text{Formula: } \frac{D^2 \times .7854 \times MP \times R \times 2S}{33000} = \text{horse-power.}$$

D^2=Diameter of cylinder.
MP=Mean pressure.
R=Revolutions.
2S=Double the stroke.

Same sum, by the short method, using constant .0000238.

```
              107 inches diameter of cylinder.
              107
              ---
              749
             1070
             ----
            11449
            12.75 lbs. mean pressure.
            -----
            57245
           80143
          22898
         11449
         --------
         14597475
            107.4 double revolutions.
         --------
         58389900
       102182325
      145974750
      -----------
      15677688150
                4 ft. stroke.
      -----------
      62710752600
       .0000238   constant multiplier.
      -----------
      50168520800
    1881322568
    1254215052
    ----------------
    1492.5158908800 horse-power.
```

Calculate the horse-power of an engine 59 inches diamete of cylinder, 33.3 pounds mean pressure, 4 feet stroke and 53.7 revolutions per minute:

```
          59 diameter of cylinder in inches.
          59
        ----
        3481 square of cylinder in inches.
       .7854
   ---------
   2733.9774 area of cylinder in inches.
        33.3 mean pressure.
  ----------
 91041.44742
           8 ft. stroke doubled.
 -----------
728331.51936
        53.7 revolutions per minute.
 -----------
33000 { 3)3911405.811632
        ---------
        11)130380.1
         -------
          1185   horse power of engine.
```

Or, $59 \times 59 \times 33.3 \times 4^2 \times 107.4 \times .0000238 = 1185$ H P.

Example H P Engine:

Cylinder 40 inches diameter, 10 feet stroke making 20 revolutions per minute, steam pressure 30 pounds per square inch, vacuum 26 inches or 13 pounds.

```
Calculation:          40 inches.
                      40
                     ---
                    1600
                   .7854
                    ----
                    6400
                   8000
                 12800
                11200
                --------
                1256.6400 square inches in piston.
      Steam 30
     Vacuum 13
            --    1256 square inches.
Total pressure 43   43 pressure.
                  ----
                  3768
```

3768
5024

54008 $10 \times 20 \times 2 = 400$ feet.
400 feet per minute.

$33000)21603200(654\frac{21200}{33000} = \text{H P}$
198000

180320
165000

153200
132000

21200

Making 654 and a fraction horse-power. In this example the steam following full stroke and the engine exerts its greatest power.

NOTES ON THE SLIDE VALVE.

The area of port opening for any slide valve should be such that the velocity of the steam in passing through it will not exceed 100 feet per second. The accompanying table can be used in determining the area:

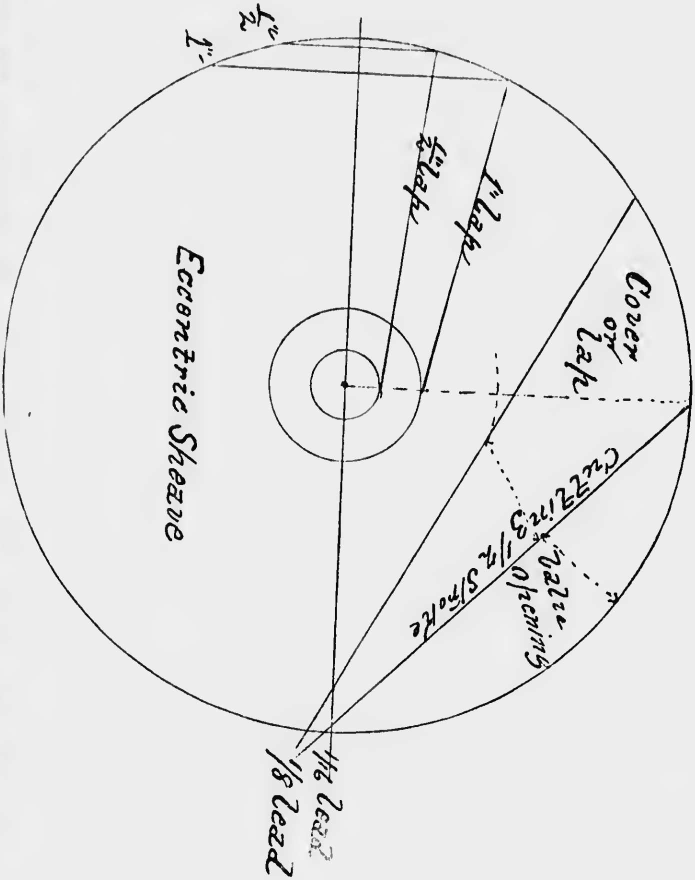
Speed of piston in feet per minute:	100.	200,	300,	400,	500
Port area=piston area multiplied by	.02	.04	.06	.07	.09

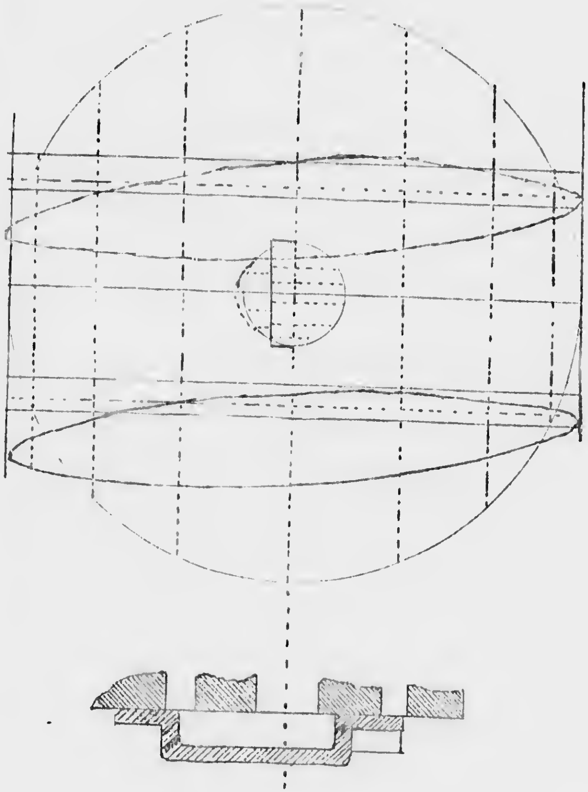
600.	700.	800.	900.	1000.	1100.	1200.
.1	.12	.14	.05	.17	.19	.2

Thus for an engine with a cylinder 40 inches diameter, 4 feet stroke, 50 revolutions per minute, the port area should not be less than $1256.6 \times .07 = 88$ square inches; and if the length of the port is equal to the diameter of the cylinder, its width is $88 \div 402.2$ inches. The width of opening given by the motion of the valve is frequently greater than the width of port, so that the bridge between steam and exhaust ports should be wide enough to prevent a leak into exhaust due to over travel.

RULE.—Minimum width of bridge equals width of steam port$+\frac{1}{4}''-$width of steam port.

Width of exhaust port equals width of steam port+travel of valve÷2—width of bridge.


Eccentric Sheave
Cover or Lap
Valve opening
1/16 Lead
1/8 Lead



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DRAUGHT OF BOILER FURNACES.

The question frequently arises, "What is the proper way to regulate the draught of a steam boiler furnace—by opening and closing the ashpit and furnace doors, or by means of a damper in the flue leading from boiler to chimney?"

There is some difference of opinion and practice regarding this matter, which probably arises from differences or peculiarities in the constructive details of various boiler plants, which might make it desirable or even necessary to regulate one way in one case and the other way in another case.

Our own preference is decidedly in favour of regulating the draught by means of a damper placed in the uptake or pipe leading from the front end of the boiler, smoke box, or front connection to the main flue. This uptake should be made of wrought iron, and rivetted securely to the boiler shell, and the damper should be fitted as close to its lower end or the tube openings as possible, and be provided with a convenient hand attachment whereby it may be set at any desired point and secured there.

There is much less liability of burning out the grates in a boiler furnace when the draught is regulated by a damper than there is when it is regulated by the ashpit door. For, let the ashpit door be closed tightly, and all circulation of air in the ashpit is stopped; there is nothing to prevent the heat from the layer of incandescent fuel being transmitted downward and overheating the grates, and overheating means warping, twisting, and cracking of the bars, and we have known them to be melted from this cause.

When, on the contrary, the ashpit doors are fully open, there is nothing to prevent the free circulation of air throughout the pit, and the bars are kept cool. We recommend omitting altogether doors to the ashpit, and making the opening through front nearly the full width of the grate, and making a water cavity or trough at least six inches deep in the bottom of the ashpit. This should be kept full of water, as it has a great effect upon the temperature below the grates.

For ease and certainty of regulation, a damper placed in the uptake, as described above, possesses great and obvious advantages over any manipulation of ashpit or furnace doors. Any one who has had charge of boilers fitted up in this manner can readily appreciate the truth of this statement.

There is, also, in our opinion, decidedly less loss of heat by infiltration of air through cracks in the setting walls when the draught is governed by a damper in flue than there is when the doors are used for same purpose; for, when ashpit doors are tightly closed, the draught of the chimney will draw air in through every crack and crevice in the walls, and this air entering the furnace at all points has a cooling tendency which it is most desirable to avoid.

The damper should always be so fitted and adapted to the boiler that, when it is tightly closed as far as it can be by the apparatus provided for operating it, it will allow sufficient draught to just keep the fires going, and carry off any coal gas which may be generated in the furnace.

The foregoing relates more particularly to boilers used for power purposes, and those plants of such size as to require the constant supervision of an engineer or fireman. With many of the small house heating boilers where the draught is automatically regulated, it is deemed expedient by most steam fitters to regulate the draught by the ashpit door.

THERMOMETERS.

To change degrees of Fahr. to degrees of Cent.: If above freezing point, from the degree of Fahr., subtract thirty-two; multiply the remainder by five; divide the product by nine. If below freezing point, first *add* thirty-two; then multiply by five and divide by nine.

To change degrees of Cent. to degrees of Fahr.: If above freezing point, multiply by nine and divide by five, and add thirty-two. If below freezing point, multiply by nine, divide by five and subtract thirty-two. Or, double the degrees Cent.: deduct ten per cent. and add thirty-two, when above freezing point; when below freezing point, proceed as above and deduct from thirty-two.

HOW SMOKE IS FORMED.

The following are the views of a correspondent in the London "Iron" on this subject:

"It is well known to every one that when fresh coals are placed on a fire in an open fire-grate, smoke arises immediately and the cause of this smoke is not very far to seek, as it will be easily understood that before the fresh coals were put upon the fire within the grate, the glowing coals radiated their heat and warmed the air above, and thereby enabled the rising gases at once to combine with the warmed air to produce combustion; but when the fresh coals are placed upon the fire they absorb the heat and the air above remains cold.

"By gases, I mean the gases arising from coals while on or near a fire; and it may not be known to every one that we do not burn coals, oils, tallow or wood, but only the gases arising therefrom. I can make this clear by the lighting of a candle, which will afford all the information required. By lighting the candle fire is set to the wick, which by its warmth melts a small quantity of tallow below; and this melted tallow is directly absorbed by the capillary tubes of the wick, and thereby so very finely and thinly distributed that the burning wick has heat enough to be absorbed by the small quantity of dissolved tallow to form the same into gases, and these gases burning, combined with the oxygen in the atmosphere, give the light of the candle. A similar process is going on in all other materials; but coal contains already about seventeen per cent. in weight of gases, which liberate themselves as soon as they get a little warm. The smaller the coal, the more rapidly will the gases be liberated, so that in many cases only part of the gases are consumed.

"To return to the subject, the fact is that the volatile rising gases from the coal cannot combine with the cold air for combustion, still a combination does take place in the following way: The cold air in the act of combination, absorbs a part of the warmth of the rising gases, which they cannot spare, and therefore must condense, so much so that all particles are formed, which aggregate, and are called smoke, and, when collected, produce soot; but so long as these particles and gases are floating they cannot burn or produce combustion, as they are surrounded by a thin film of carbonic acid. It is only when collected and the acid is driven off that they burn rapidly.

"I have now shown that cold air is the cause of smoke, which may be greatly reduced by care. In the open fire-grate the existing fire ought to be drawn to the front of the grate and the fresh coal placed behind or on the back of the fire. The fire in the front will then burn more rapidly, warm the air above, and prepare the rising gases for combustion. In this way smoke is diminished, as the gases from the coals at the back rise much more slowly than when placed upon the fire and the air partly warmed. The same process may be applied to kitcheners, thereby almost entirely preventing smoke after the first lighting. For stoves and boilers, warm air may be produced for the entire combustion of all gases."

SCALE IN BOILERS.

In the experience of the steam user there is probably no one cause more prolific of danger or more wasteful of steam power than scale in boilers. The great saving in fuel and time is evident when it is known that a scale one-fourth inch thick requires an extra expenditure of sixty per cent. more fuel. Scientific experiments show the conducting power of scales as compared with iron is as one to 35.5; consequently, to raise water in a boiler to any given heat, the fire surface of the boiler must be heated to a temperature in accordance with the thickness of the scale. To raise steam to a pressure of ninety pounds, the water must be heated to 320 degrees Fahrenheit. In a clean boiler of one-fourth inch iron this may be done by heating the external surface of the shell to about 325 degrees. If one-half inch of scale intervenes between the shell and the water, such is the non-conducting power that it will be necessary to heat the fire surface to about 700 degrees, almost red heat. This excessive heat causes the oxidization of the metal, and it becomes granular and brittle, and is liable to bulge, crack, or otherwise give way to the internal pressure, with the dangerous results which follow such conditions.

After long and exhaustive experiments, looking to the destruction and prevention of scale, the Ohio Scale Solvent

Co., of 29 Glen Building, Cincinnati, Ohio, now confidently offer their scale solvent with the assurance that it has no deleterious effect upon the iron, and that it will entirely remove all scales that have formed in the boilers, and will completely resist the formation of any new scale, by holding the mineral salts in the feed water in a sludgy sediment until it can be blown out through the blow cock or otherwise. With this preparation the difficulty of using the hard water of wells or from other sources is entirely overcome, and the increased safety in the use of boilers and great economy in the consumption of fuel is assured, thus saving the additional cost of repairs and extra time and labor in cleaning out, and also saving valuable time of employes frequently lost by delay. This solvent is a dry powder which will not deteriorate by exposure to the weather. It is mixed thoroughly in a bucket of warm water and administered at the man-hole, safety-valve, through the feed water pump, or any other convenient manner, and costs only from two to five cents per day for each boiler.

SUPERHEATED STEAM.

It seems a little remarkable, says the London "Engineer," that in the pursuit of economy of fuel, engineers have abandoned superheating. Years ago its value was well understood, and the superheater was found in almost all ships pretending to have good engines and boilers; but the boilers which in the present day are fitted with true superheaters may be counted almost on the fingers. The reason why superheating was given up is to be found in the fact that the thing was overdone. We have heard of instances in which the steam was so much heated that it would scorch paper, and did carbonize and ruin the piston-rod packings. No amount of saving in fuel could compensate for this. Another objection to superheating lay in the fact that it appeared to exert a species of solvent effect on the cast iron of port faces, the edges of the ports becoming in time so brittle and soft that they could be dug out with a pen-knife. We have reason to think, however, that, although superheating was a failure ten or fifteen years ago, it need not be a failure now, the conditions under which it can be employed being much more favorable than they used to be. What we are about to say on the subject is not intended to apply solely to marine engines, but to all steam engines which are intended to be economical.

The conditions of application are more favorable than they have been; first, because more is known about superheating than was known, and there is consequently less chance of it being overdone; and, secondly, the use of very high pressures has led to the production of better castings than those previously made. Again, asbestos and metallic packings are now available, which were unknown before; and, lastly, mineral oils can be used as lubricants instead of the tallow which alone was at the service of the engineer as a cylinder greaser. Twenty years ago, when Mr. Adams first tried to use very high pressures—150 pounds to 160 pounds—on the North London Railway, great trouble was experienced from the cutting of the cylinders. The high temperature of the steam, 370°, volatized or carbonized the oil, and the metal appeared to be attacked in much the same way as though superheated steam was used; but after a few trials a mixture of irons was found, and a system of casting adopted which got over the difficulty, and pressures of 160 pounds are now freely used without any inconvenience. If we assume that 350° is a safe temperature, then it follows that steam of eighty-five pounds with a temperature of 328° might have 25° or thereabout of superheat imparted to it without the least danger. Indeed, we may go further than this, because the steam is certain to be cooled down the moment it enters a cylinder, so that a greater degree of superheat would do no harm. The advantage to be derived from the use of a superheater is two-fold. In the first place, it will send dry steam, not a mixture of steam and water, into the engine; and, secondly, the superheat will tend to prevent cylinder condensation. Before any of our readers can understand the advantage to be derived in this way, however, they must realize the loss caused by the use of wet steam, or rather by the presence of moisture in a cylinder.

The great foe to economy of fuel is cylinder condensation. If perfectly dry steam could be used this condensation would be reduced to a minimum, because dry steam, like any other gas, conducts heat very slowly. If the walls of a cylinder were always dry, then the cooling influence of a condenser would be hardly felt, for reasons which may be easily explained in a few words. If a surface is wetted and submitted to a vacuum, the moisture will evaporate freely, taking up the heat necessary for evaporation from the surface on which it rests. If the vapor is continually drawn off, as by the air pump of a condensing engine, the evaporation and absorption of heat will be intensified, as may be easily shown by a simple experiment. Sulphuric acid is extremely greedy of water; if some be placed in a saucer under the receiver of an ordinary air pump, and a watch glass containing water is placed near it, also under the receiver, as soon as the pump is worked and the pressure reduced, vapor will be given off by the water and immediately seized by the acid; and so much heat will be carried off in this way that the water will quickly be frozen if the watch glass rests on a bit of wood or other non-conductor from which it cannot get heat. Just the same action takes place at every stroke in a steam engine, and the amount of loss will be measured for one thing by the quantity of moisture in the cylinder.

Ordinary saturated steam is a very different thing from a permanent gas. It is in what chemists call the critical condition. Its molecules are in unstable equilibrium, and the least deprivation of heat causes condensation. When steam is superheated it acquires different properties. Among others it is much more mobile. Mr. D. K. Clark has pointed out in his treatise on the locomotive, that engines with outside cylinders always have more back pressure than engines with inside cylinders, because, the outside cylinder being cooler than the inside cylinder, the steam is wetter and the exhaust more sluggish. Smaller ports and passages will do with gaseous than will suffice with saturated steam. It must not be forgotten that steam is considerably increased in volume by superheating. The late Dr. Siemens found that steam of 212°, superheated, but maintained at atmospheric pressure, augmented rapidly in volume until the temperature rose to 220°, and less rapidly up to 230°, or 18° above saturation point; from thence it behaved like a permanent gas. Ordinary saturated steam may be made gaseous by superheating it from 10° to 20°. According to Regnault, the total heat of gaseous steam is about $2\frac{1}{2}$ per cent. greater than that of saturated steam.

It is well known to most engineers in the present day that a portion of the heat contained in steam is converted into work, so that even in a perfect non-conducting cylinder, if such a thing could be had, some steam must be condensed. Now it so happens that working steam will always give up its superheat before anything else, and therefore it is quite possible, theoretically, to work an engine without any cylinder condensation whatever, the whole of the heat converted into work being derived from the superheat. Such an engine would work with maximium economy. Let us assume that .3 pound of steam per minute developes one horse-power in a given engine; the total quantity of heat in it will be, let us say $+.3=354.3$ units, of which we may suppose that 324 are due to the fuel, the temperature of the feed water being 60°. A horse-power represents only 42.74 units per minute. The specific heat of saturated steam is .305, that of gaseous steam is .475, under constant pressure. If we take the latter figure, then it would be necessary to superheat $\frac{1}{3}$ pound of steam by 90°. If its pressure were eighty-five pounds, its temperature while saturated would be 328°, and $328+90=418$, which would be too high for ordinary use, corresponding as it would to a pressure of about 420 pounds on the square inch absolute. The whole of the work would, however, come out of the superheat, and if the cylinder had a very thin liner, and was jacketed with superheated steam, it is more than probable that an extreme degree of economy would be attained. Although we do not assert that it would be desirable to push superheating so far as this, we would earnestly impress upon steam users the importance of adopting some arrangement by which dry steam may be admitted to the cylinders of the engines; even a steam-trap fitted on the steam pipe near the engine will be useful. It is not as generally known as it ought to be that all Lancashire and Cornish locomotive boilers supply steam which contains from five to eight per cent. of moisture in the shape of insensible priming. Some of this can be "knocked out" of steam by the use of baffle plates; but in all cases where it is possible some arrangement for drying the steam thoroughly should be adopted.

WHAT THE BEST INFORMED THINK ABOUT BOILER EXPLOSIONS.

The following, by H. Walther-Meunier, is from the "Bulletin de la Societe Industrielle de Mulhouse," 1885, p. 113: "The author, in response to numerous inquiries, has studied the question of the possibility of boiler explosions caused by the superheating of water in the boiler—that is, the heating of water to a temperature higher than that due to the pressure. He notices the results of various laboratory experiments on the subject, which lead to the following conclusions: 'That the state of absolute repose is indispensable for the production of the phenomenon of superheat of water; and that the presence of air or other gas, even in indefinitely small proportions, maintains ebullition under normal conditions. He finds from the official statistics of boiler explosions for six years 1877–82, in England, France, and Germany, that the proportion of explosions from unknown causes were eight in one hundred and fifty for England, thirteen in one hundred and fourteen for France, and three in one hundred for Germany. These average about six and-a-half per cent. But, on closer examination, the proportion of totally unknown causes for France is reduced to three per cent. For Germany there is no cause classed as totally unknown; and for England only one per cent., making a total average of 1.1 per cent. of totally unknown causes. This percentage is easily explained, in the face of the difficult and laborious work of investigation after an accident, without needing to ascribe its origin to the existence of superheated water. The author maintains that, in a steam boiler, whether at work or at rest, there is continual agitation and circulation arising from differences of temperature; and that superheating of water in the boiler is impossible. Besides, the presence of the smallest quantity of air is sufficient to impede or prevent superheating of water—a condition which is always fulfilled in practice, and which is clearly confirmed by the fact noticed by the author, that, at the temperature of discharge of condensing water, eighty-six degrees Fahrenheit, the tension of the vapor is 0.041 atmosphere, whilst there is never less than 0.12 atmosphere of back pressure, making the difference 0.079 atmosphere, which is only explained by the pressure of air.

"After a consideration of the conditions of boilers of different types, the author concludes that all boiler explosions may be explained by bad materials, bad construction, bad design, or want of care and precaution, or too much pressure for the strength of the boiler."

INDICATOR.

A small instrument, called the indicator, is used by engineers to ascertain the pressure of steam, etc., at each point of the stroke of the engine, by which they get the actual power and form of the figure of the diagram. The engineer, from knowledge and experience, concludes causes by its variations, the errors and defects of his engine, and applies the proper remedies, and thus this ability is one of the highest attainments of an engineer. The indicator is a small piston working in a cylinder with considerable clearance, carrying a pencil at the end of its piston-rod. One end of the indicator cylinder is placed in communication with one of the ends of the cylinder, of which it is desired to know the horse-power, etc., by pipe and cock, and the other end is in free communication with the air by means of the loose stuffing-box through which the piston-rod of the indicator moves, and by means of a hole in the cylinder of the indicator, so that steam going into the main cylinder of the engine a part is admitted to the bottom side of the indicator piston, while on the other side is the atmospheric pressure. The movement of the piston is regulated by a spiral spring attached to the cover of the indicator at one end and to the piston of the indicator at the other; as the steam pressure is greater or less in its pressure, so the spring is compressed more or less. A piece of paper is held on the indicator cylinder in front of the pencil to register the various indications of pressure. Each make of instrument requires a treatise specially devoted to it, describing arrangement of parts, principle, and manner of fixing and operating, etc., and the student will do well to study the instrument he is using; most of the makers now issue a pamphlet descriptive of their indicator, also giving rules, diagrams, and a full explanation of everything pertaining to its use. The following description of the Crosby indicator is taken from a pamphlet on that subject by George H. Crosby, the inventor of the Improved Parallel Motion Steam Engine Indicator:

"The principle and action of indicators are so simple, and to most practical engineers now so well understood, that it will only be necessary to give the following cut and description of the parts of this instrument to readily appreciate the advantages accruing from its use."

The general principles of indicators are the same, though there are two classes; those where the piston travels with the pencil, and those where the pencil moves a greater distance than the piston of the indicator; the latter system is generally given the preference, but none of them are yet perfect, though many valuable new inventions have been made, and contrivances added to the instrument of late years and better results are being attained every year, still some difficulty exists in procuring good diagrams from high speed engines, even with special indicators for this class of machinery.

The best form of diagram for an expansion engine is that which comes nearest the true curve, which is called the hyperbolic or Naperian curve of the cut off, showing that the valve correctly set, valve and piston tight, with right clearance, etc.; but in most cases in practice it will fall short of the theoretical curve, being a little below; if much below it is caused by a leak in the steam valve. An experienced engineer can tell at a glance whether an engine is in good working order by seeing its card. By engineers comparing their cards and the practical results under different arrangement of their engines, much useful knowledge may be obtained regarding their special style of engine, not to be readily obtained or even found in books; but for the general rules, cards, information and finding out of faults of the diagrams, I would refer the student to the works of Read, Ainsley and Roper, also Appleton's "Applied Mechanics," which works are now generally to be found in the libraries of every student of marine engineering, but in this and other important subjects where the students have to purchase, I would always recommend them to get a book specially devoted to the one subject and more especially such a subject as the indicator; the student will find Professor Chas. T. Porter's work, "The Steam Engine Indicator," to cover the most important part, or N. P. Burgh's "Indicator Diagram Practically Considered." It is now universally admitted that the steam engine indicator is a most valuable appendage to the steam engine, and when successfully used and intelligently understood, its value can hardly be too highly estimated.

The following rules and diagrams are inserted so the student may have a slight general idea of the indicator, especially so far as is required for him to successfully pass the Board of Steamboat Inspection examination on that subject:

Rule for calculating the mean pressure on the piston throughout the stroke from the indicator diagram.

1. Divide the diagram in the direction of its length into ten equal parts by drawing nine ordinates, or lines, perpendicular to the atmospheric line, at equal distances.

2. With the scale to which the indicator is constructed, measure between the spaces the distance from the atmospheric line to the upper outline (or the steam side) of the diagram until this crosses the former, if it does so. Next, repeat the process for the area between the atmospheric line, or the expansion curve, after it has crossed this line and the lower outline diagram.

3. Take the sum of the measurements of the steam side, then of the vacuum side, and divide by ten in each case.

4. Add vacuum to steam, which gives the total mean pressure for each part of the stroke.

In finding the mean effective pressure of the diagram, it is not at all necessary to take the steam and vacuum effects separately. The usual and most expeditious mode is to proceed thus:

(*a*) Take measurements at once completely across the diagram, that is, measure between the space from the vacuum line to the steam line; note these scales distance down.

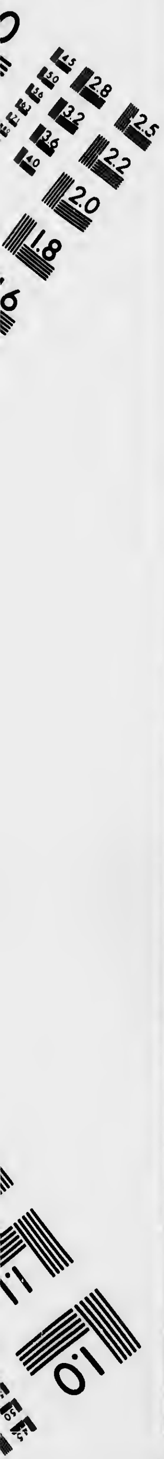
(*b*) Add the whole together and take the mean by dividing by ten; the result is the total mean pressure.

In the case of a double diagram, or diagrams from the top and bottom of cylinder combined, proceed as directed in Nos. 2, 3 and 4, or as directed in (*a*) and (*b*), then

5. Lastly, add top and bottom together, and divide by two; the result is the average of both, or the mean pressure for the whole double stroke.

There is a simple plan by which a person with but little knowledge of the method of working indicator cards can take the separate value of the steam and vacuum pressure from an indicator diagram; it is one often employed in the steam department of the British Admiralty:

The atmospheric line is taken as equal to fifteen pounds, and from this line, as a point of departure, fifteen other lines are marked by the scale, thus coming below the vacuum line of the engine up to the true vacuum line of a perfect exhaust. The lowest line is then taken as the zero or datum line, and



the actual pressure (not the relative pressure) as compared with the atmosphere of both the steam and vacuum line can thus be obtained. The difference between the two pressures gives the gross or actual pressure on the piston.

THE PRINCIPAL FUELS USED FOR STEAMERS IN CANADA.

The principal fuels used in Canada for steam-making are coal and wood. At one time wood was used to a great extent, but of late years coal has superseded it in many steamers, and on small steamboats on inland lakes and the upper part of rivers for high-pressure steamer or tugboats employed at rafting. Dry bituminous or soft coal is mostly used, and is found and mined quite extensively in the Maritime Provinces at Pictou, Sydney, Lingan, Springhill, Joggins, Newcastle, also at Vancouver Island, B. C., and in the great Saskatchewan Valley are cretaceous, and toward the north, along the McKenzie river, a brown lignite kind of coal is abundant.

The "Gororia" mine in Cape Breton gives the following analysis:

	PER CENT.
Volatile matter	27.08
Fixed carbon	60.45
Ash	7.25
Sulphur	3.42
Moisture	1.80
	100.00

Brown, in his work on the coal fields of Cape Breton, says: "Notwithstanding the large quantity of ash in this coal it is much esteemed for making steam." The coal found at Newcastle, New Brunswick, is not regularly mined to any extent, but is prized for use by blacksmiths.

The following analysis of the "O'Leary" seam, at Newcastle, N. B., is by a Glasgow, Scotland, chemist:

		PER CENT.
Volatile matters		32.12
Coke	Fixed carbon	56.44
	Ash	6.70
Sulphur		4.10
Moisture		.64
		100.00

The following is an English analysis of Vancouver Island coal, but no special mine is mentioned:

	PER CENT.
Carbon	66.93
Hydrogen	5.32
Nitrogen	1.02
Sulphur	2.20
Oxygen	8.70
Ash	15.83
	100.00

A good deal of English coal is used at the seaports of Canada, as vessels bring it instead of ballast, and American hard coal is commencing to work itself into use everywhere, on account of its steaming qualities and cleanliness, especially for summer passenger boats and pleasure excursion steamers. Wood, when newly felled, contains a proportion of moisture which varies very much in different kinds and specimens, ranging from thirty to fifty per cent., but generally being about forty per cent. Perfectly dry wood contains fifty per cent. of carbon, the remainder consisting either of oxygen and hydrogen or water. The coniferous family (spruce, pine, etc.), contains a small quantity of turpentine, which is a hydro-carbon. The total heat of combustion in wood is about the same, being due to the fifty per cent. of carbon. As a relative example of the equivalent value of wood and coal the account of the amount of vegetable matter or vegetation in coal may be interesting. Wood affords in general about twenty per cent. and coal eighty per cent. of charcoal. Neglecting the oxygen and hydrogen, therefore, it must have required four tons of wood to yield the charcoal, which we find in one ton of coal. Let us, then, suppose a forest composed of trees eighty feet high, that the trunk of each tree contained eighty cubic feet, and the branches forty, making 120: the weight of such a tree, at 700 specific gravity, will be two and-a-quarter tons; and allowing 130 tons to an acre, we have 300 tons on that space. Supposing that which falls annually, leaves and wood, to be equal to one-thirteenth, we have ten tons of wood annually from an acre, which yields two tons of charcoal; and this charcoal, with the addition of bituminous matter called bitumen, forms two and-a-half tons of coal. Now a cubic yard of coal weighs almost exactly one ton; and a bed of coal one acre in extent, and three feet thick, will contain 4,840 tons. It follows, therefore, that one acre of coal is equal to the produce of 1,940 acres (*i. e.*, 4,840 divided by two and-a-half) of forest; or if the wood all grew on the spot where its remains exist, the coal bed three feet thick and one acre in extent must be the growth of 1,940 years. Even if we suppose the vegetation like that of a tropical climate, to be twice as rapid as I have assumed, we shall still require about 1,000 years to form a bed of coal one yard thick, and, as an example of a coal field for the thirty-six yards of coal in a coal field a period of 36,000 years.

Seeing that coal is the most valuable of all the treasures the earth has preserved for us, therefore no apology is needed for assigning so many articles to its consideration in this work. We have seen that it is matter which owes its existence to vegetable growth, and that, buried beneath vast accumulations of shatified deposits, this vegetable matter has undergone, in the lapse of ages, a process called bitumensation, a species of metamorphism which has generally obliterated all traces of vegetable construction in the coal. The stored-up sunlight that produced the growth of the forest that produced the material coal again gives out light and heat to the world after many ages.

NOTES ON THE SCREW PROPELLER.

The screw propeller has many different forms and members of blades, and has been divided into classes named from inventor, form or number of the blades and their shape, but they may all be roughly classed as 'right-handed' and 'left-handed.'

A right-handed propeller is a propeller whose blades form part of a right-handed screw of a certain pitch, revolving from port to starboard. A left-handed propeller is a propeller whose blades form part of a left-handed screw, and it revolves from starboard to port of the steamer.

A screw of increasing pitch is not one of uniform pitch, but one that the pitch increases from the leading edge to the following edge of the blade, or from the centre to the circumference, or both; a screw with a uniform pitch being one in which the pitch is the distance between the threads which is constant.

Engine makers generally fit a right and a left-handed propeller to a twin screw steamer, as it is advisable that the crank should revolve in the same direction as regard the cylinders, one on each side of steamer.

The slip of a screw propeller is the difference between the actual speed of the slip and the speed of the screw, or in other words, it is the amount of the work lost from the screw revolving in water, a yielding substance. Its amount is expressed in figures as so much per cent. of the speed due to the pitch multiplied by the number of revolutions. A screw 25 feet pitch, 50 revolutions per minute equals 12.3 knots speed ($50 \times 60 \times 25 \div 6080$), then suppose actual speed 11 knots equals 1.3 knots slip, which would be 10.6 per cent. slip. To find the progression of the screw and the rate of slip, the following rule may be used:

(1) Multiply the pitch of propeller by the number of revolutions per minute and this product by sixty; this last result

divided by 6080 is the progression of propeller per hour in knots.

(2) Take the amount of slip per cent. from 100; then say, as 100 is to remainder, just found, so is rate of progression of propeller (1) to the rate of the slip.

The rule to find the required number of revolutions it must take to advance at a given rate, viz.:

(1) Find the number of feet in the knots per hour by multiplying the knots by 6080 feet.

(2) Divide the product (1) by the pitch of the screw or distance moved in one revolution. The quotient is the number of revolutions required.

NOTES ON THE PADDLE-WHEEL.

The common radial paddle-wheel has the "floats" rigidly fixed on the arms; with cast centres; arms of wrought iron; bolts with one end turned back to grip the back of arm, the other secured with a nut and washer. Some paddle-wheels are made with a few cast iron floats for the purpose of counterbalancing the weight of the moving parts of the engine. The metal float is placed so that when the centre of the weight is at the bottom of the wheel, the crank has a slight lead for the downward stroke. A common radial paddle-wheel differs from a feathering-wheel, in having floats fixed to the arm with their face parallel to the centre of the wheel, while the feathering paddle-wheel has its floats to oscillate, or move on the centre, and are so regulated by an eccentric that their faces, while immersed, are nearly at right angles to the surface of the water. In a feathering float there is very little waste from friction, as may be seen by this construction. The centre of the wheel eccentric is forward of and in a horizontal line with the centre of the shafting. The working surfaces of a feathering-wheel are made of brass and are lubricated with water by the wheel.

Disconnecting paddle-wheel engines are worked separately or together, the wheel slides on keys let into shaft, moved levers, etc. This kind of paddle-wheel engine is very useful for tug-boats or steam ferries, as they are quick and handy.

The speed of a paddle-wheel steamer may be calculated by the following rule:

Diameter of the wheel in feet multiplied by 3.1416 multiplied by the number of revolutions of the engine in an hour, divided by 6080 equals knots per hour.

The number of revolutions that an engine must make per hour to drive a steamer a given number of knots can be ascertained by the following rule:

(1) Find the circumference of the paddle-wheel by multiplying the diameter by 3.1416.

(2) Find the number of feet in the knots the paddle-wheel is driven per hour by multiplying the number of knots by 6080 feet.

(3) Next find how often this last (2) contains the distance moved in one revolution (No. 1); the result is the number of revolutions required.

SQUARE AND CUBE ROOT.

Find the square root of 627264.

The greatest square in the first period, sixty-two, is the square of seven, or forty-nine. Subtracting forty-nine from sixty-two, we place seven as the first figure of the root. We bring down the next period, seventy-two, to the right of the remainder, thirteen, for a dividend, doubling seven to form a partial divisor, which is contained in 137 (the dividend without the right hand figure two) nine times. We annex the nine both to the partial divisor and to the part of the root already obtained. Multiplying 149 by nine, we subtract the product, 1341, from the dividend, and bring down the next period, sixty-four, to the right of the remainder for a dividend, doubling seventy-nine, the part of the root already obtained, for a partial divisor, 158, is contained twice in 316, and annexing the two both to the partial divisor, 158, and to seventy-nine, the part of the root already obtained, we multiply the divisor, 1582, by this last figure of the root; the product is 3164, which, subtracted from the dividend, leaves no remainder. Hence 792 is the exact square root of 627264.

```
       ·  ·  ·
     627294(792
     49
     ----
149)1372
    1341
    ----
1582)3164
     3164
     ----
```

Find the square root of 7.3441.

Placing a dot over the figure in the unit's place, we put one over every second figure to the right, and then performing the operation as if 73441 were a whole number, as indicated in the margin, we get 271 as the root. We cut off two decimal places from this, because there are two dots over the decimal part of the original decimal.

The square root is therefore 2.71.

```
      ·  · ·
      7.3441(2.71
      4
      ─
 47)334
    329
    ───
541)541
    541
    ───
```

OBSERVE.—At any stage of the process the product of the completed divisor into the last figure of the root must not exceed the dividend. Hence, in finding the figure to be placed in the root, care must be taken to observe whether, when the multiplication is effected, the product will exceed the dividend or not. Thus, in the last example, in the case of the dividend 334, the partial divisor four will go eight times in thirty-three, but since the product 8×48 is greater than 334, seven is the next figure of the root, and not eight. In the case of a decimal, if the number of decimal places be odd, it should always be made even by annexing a cipher, in order that the last period may be completed.

Find the square root of 41.34156.

Here, adding a cipher, we point the decimal thus:

```
         41.341560(6.429
         36
         ──
    124)534
        496
        ───
   1282)3815
        2564
        ────
        125160
        115641
        ──────
          9519
```

And there will be three decimal places in the square root obtained. Here there is a remainder, or the given decimal is not what is called a complete square. By adding, however, more ciphers, more and more figures can be obtained in the root, to any extent of approximation.

This is a similar case to that of square root of seven, spoken of in Art. 2. To approximate to the square root of seven, we should proceed thus:

```
      7.0000(2.64
      4
      ---
  46)300
     276
     ----
 524)2400
     2096
     ----
      304
```

By continually adding ciphers we can carry the approximation to any degree of neatness.

Similarly in the case of any whole number which is not a complete square root, an approximation to the root by means of decimals can be obtained. The integral part of the root obtained is, of course, the square root of the largest integral complete square, which is less than the given number.

The square root of a fraction is obtained by taking the square root of the numerator for a numerator, and the square root of the denominator for a denominator. This follows at once from the consideration that the multiplication of fractions is effected by multiplying the numerator for a numerator, and the denominator for a denominator. When either the numerator or the denominator is not a complete square, in which case the fraction itself evidently has no exact root, instead of finding an approximate root of both numerator and denominator in decimals, and then dividing one by the other, it will be better first to reduce the fraction to a decimal, and then to take the square root.

EXAMPLE.—To find the square root of two-sevenths.

Reducing two-sevenths to a decimal, we find it to be .285714.

Hence, we should find by the previous method the square root of .28571428571428....to as many decimal places as we please by continually taking in more and more figures of the recurring periods.

Similarly in finding the square root of two-fifths, we should proceed thus: two-fifths equal to .4, and then find the square root of .400000, etc., to as many places as we please. It does not follow that because the numerator and denominator of a fraction are not complete squares, that the fraction has no square root; for the division of numerator and denominator by some common measure may reduce them to perfect squares. Thus, $\frac{28}{63}$, when numerator and denominator are divided by seven, gives four-ninths, the square root of which is two-thirds. A fraction must be reduced to its lowest terms to determine whether it be a complete square or not.

ABBREVIATED PROCESS OF EXTRACTION OF SQUARE ROOT.

When the square root of a number is required to a considerable number of decimal places, we may shorten the process by the following rule for the contraction of the square root process.

Find, by the ordinary method, one more than half the number of figures required, and then, using the last obtained divisor as a divisor, continue the operation as in ordinary long division.

Find the square root of two to twelve figures.

```
        2.0000(1.41421356237
        1
       ---
    24)100
        96
       ----
   281)400
       281
       ----
  2824)11900
       11296
       ------
 28282)60400
       56564
       ------
282841)383600
       282841
       -------
       10075900
```

```
2828423)10075900
           8485269
           --------
           15906310
           14142115
           --------
            17641950
            16970538
            --------
             6714120
             5656846
             -------
            10572740
             8485269
            --------
             20874710
             19798961
             --------
              1075749
```

Here having obtained by the ordinary process the first seven figures, we get the rest by dividing as in ordinary division by the last divisor, 2828423.

We might extract the square root of a perfect square by splitting it into its prime factors, but unless the number is not large this would be a tedious method.

Find the square root of 441.

Following the method given in Lesson VIII., Art. 5:

```
3)441
  ---
3)147
  ---
   49
```

Therefore $441=3^2\times7^2$, of which the square root is 3×7, or twenty-one.

OBSERVE.—Unless a number is made up of prime factors, each of which is repeated an even number of times, it is not a perfect square.

EXTRACTION OF THE CUBE ROOT.

To extract the cube root of a given number is the same thing as resolving it into three equal factors. As in the case of the square root we must content ourselves with giving, without explanation of the reason of its truth, the rule for the extraction of the cube root of a given number. Mark off the given number into periods of three figures each, by placing a point over the figure in the unit's place, and then over every third figure to the left (and to the right also if there be any decimals). Put down for the first figure of the root the figure whose cube is the greatest cube in the first period, and subtract its cube from the first period, bringing down the next period to the right of the remainder, and thus forming a number which we shall call a dividend. Multiply the square of the part of the root already obtained by three to form a divisor, and then, having determined how many times this divisor is contained in the dividend without its two right hand figures, annex this quotient to the part of the root already obtained. Then determine three lines of figures by the following processes:

Cube the last figure in the root.

Multiply all the figures of the root except the last by three, and the result by the square of the last. Multiply the divisor by the last figure in the root. Set down these lines in order, under each other, advancing each successively one place to the left. Add them up, and subtract their sum from the dividend. Bring down the next period to the right of the remainder, to form a new dividend, and then proceed to form a divisor, and to find another figure of the root by exactly the same process, continuing the operation until all the periods are exhausted. In decimals, the number of decimal places in the cube root will be the same as the number of points placed over the decimal part, *i. e.*, as the number of periods in the decimal part.

OBSERVE.—If, finally, there be a remainder, then the given number has no exact cube root, but, as in the case of the square root, an approximation can be carried to any degree of nearness by adding ciphers, and finding any number of decimal places.

The rule will be best understood by following the steps of an example.

Find the cube root of 78314601.

```
          .  .  .
     78314601(
     64
     ------
  48)143.14
     ------
          8
         48
        96
     ------
     10088
     --------
5292)42266.01
     --------
          343
        6174
     37044
     --------
     3766483
      460118
     --------
```

Placing the points as indicated in the rule, we observe that the cube of four is the greatest cube in the first period, seventy-eight. Subtracting 4^3, or sixty-four, from seventy-eight, we get a remainder of fourteen, to the right of which we bring down the next period, 314, to form a dividend. Multiplying the square of four by three, we get for a divisor forty-eight, which will go twice in 143 (the dividend without its two right hand figures). We set down two, therefore, to the right of four as the next figure in the root, and then proceed to form the three lines according to the rule:

Eight is the cube of two;

Forty-eight is $3 \times 4 \times 2^2$;

Ninety-six is the product of two, the last obtained figure in the root; and forty-eight the divisor.

Placing these three lines under each other, but advancing each successively one place towards the left, and adding, we get 10088, which we subtract from the dividend, 14314, leaving a remainder, 4226. To the right of this we bring down the next period, 601, thus forming another dividend.

The next divisor, 5292, is 3×42^2, and is contained seven times in 42266. Putting down, then, seven as the next figure in the root, we find three lines as before:

343 is the cube of seven, the last figure in the root;
6174 is $3\times42\times7^2$;
37044 is 7×5292.

Adding these up, when properly placed, we get 3766483, which we subtract from the previous dividend, 4226601, leaving a remainder, 460118. There are now no more periods left. Hence, 427 is the number whose cube is the nearest cube number to the given number, and less than it. If there were no remainder, the root obtained would be the exact cube root of the given number.

In such an example as that worked out above, we could place a decimal point and as many periods of ciphers as we may wish after the original number, and thus, by continuing the process according to the rule, get as many decimal places as may be required as an approximation to the cube root.

In finding the cube root of a decimal, the periods must be completed by adding ciphers, if necessary.

When the cube root of a fraction is required, the cube root of the numerator and the cube root of the denominator will be the numerator and denominator, respectively, of the fraction which is the cube root of the original fraction. If the numerator and the denominator are not both perfect cubes when the fraction is reduced to its lowest terms (*vide* 9, Obs.) the best plan generally will be to reduce the fraction to a decimal, and then to find the cube root of that decimal. In the case of mixed numbers, they must be reduced to improper fractions, in order to see whether the resulting improper fraction has its numerator and denominator both perfect cubes.

Thus $5\frac{23}{64}$, reduced to an improper fraction, gives $\frac{343}{64}$, of which the cube root is seven-fourths or one and three-quarters.

But if, when so reduced, the numerator and denominator are not perfect cubes, then it will be better to reduce the fractional part of the mixed number to a decimal, and placing the integral part before it, find the cube root of the above rule.

Find the cube root of forty-four and three-fifths to two places of decimals.

$44\frac{3}{5}=44.6$ 44.600000(3.54
27
—
17600

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    27)17600
       -----
         125
        225
       135
       -----
       15875
       -------
3675)1725000
     -------
          64
        1680
      14700
     -------
     1486864
     -------
      238136
```

And so on to as many more decimal places as we may desire.

OBSERVE.—Exactly as in the case of the square root, when one more than half the number of figures required of the root have been found by the rule, the rest may be found by simply dividing, as in ordinary division, by the last divisor.

OBSERVE.—It will be observed that although twenty-seven, the first divisor, is really contained six times in 176, we only put down five in the root.

The reason is that, on examination, we find that six would be too large, for it would make the sum of the three lines which we add up greater than the dividend 17600. We must, therefore, always be careful to observe whether the figure put down in that root will or will not make the sum of the three lines too large. The dividing the dividend without its two last figures by the divisor is not, therefore, an infallible guide to the next figure of the root.

PART III.

SKETCH OF THE LIFE AND WORKS OF WM. M. SMITH, Esq.

(First S. B. Inspector of the Maritime Provinces.)

WILLIAM MORGAN SMITH is the second son of George Neilson Smith, C. E., surveyor and artist, of Edinburgh, Scotland, and Olivia Morgan, of Waterford, Ireland, and grandson of Adam Smith and Margory Melville, of Edinburgh, on the parental side, and grandson of Nathaniel Morgan, Surgeon of the 90th Regiment of Infantry, of Welsh descent, and Rosahanna Burns, of Waterford, on the maternal side; he was called after his uncle, William Smith, writer to the "Cygnet," Custom House, Edinburgh. His family came to Canada about the year 1823, on the appointment of his father as draughtsman and instructor of surgeons, to the Crown Land Office, at the Capital of New Brunswick, Fredericton. Mr. Smith, the subject of our sketch, attended as a school, what is now known as the University of New Brunswick, while living at Fredericton, but his education he mainly owes to his own efforts in private study and tuition, never leaving a subject, in any way connected with his business, until he had mastered thoroughly all its details; and with exception of the above mentioned schooling, he may be said to be self-educated, especially in regard to scientific subjects. When his father moved to St. Andrews, to publish the newspaper, "The Standard," Mr. Smith came to St. John, N. B., and in 1833 became an apprentice to Foulis, Ross & Hogg, proprietors of "Duke Street Iron Foundry," the mechanical manager of which was Mr. Robert Foulis, of Glasgow, Scotland, an expert for those days, and the inventor of the application of the steam whistle to the fog alarm, a machine of now world-wide renown and usefulness. Mr. Smith, after serving four years with Mr. Foulis, two of which he served as assistant engineer with him on the steamer "John Ward," on the River St. John, after his time had expired, went to Boston to perfect himself in his calling, and engaged for four years at Alger's foundry and machine shop, where the first brass cannons for the United States navy were manufactured by Babbit, the inventor of the famous non-conducting Babbit metal. After the expiration of his time, Mr. Smith returned to St. John, N. B., and assisted Mr. Foulis in erecting a side lever engine in the first ferry boat ever built at that city, called the "Victoria," and owned by the Corporation of the City of St. John, N. B., by whom Mr. Smith was appointed engineer in charge; and after the second steamer, "Lady Colbrook," was built, he became the superintendent engineer and manager of the ferries, in which capacity he served fourteen years. Mr. Smith then went to New York, and entered the celebrated machine shop of Cunningham & Bellnap, where he remained for eighteen months, to perfect himself in mechanical knowledge and drawing; the engines of the "Western Star," "Pride of the North," and the extremely fast steamer "Joseph Bellnap," were built in the establishment. Soon after leaving the above firm, Mr. Smith returned to St. John, N. B., and became one of the proprietors of the St. John and Carleton ferry steamers, at which business he remained as the manager until 1854, when he was appointed Steamboat Inspector of New Brunswick, by the Provincial Government of this Province, under the hand and seal of Sir Edmund Head, the Royal Governor; and in 1867 was appointed Steamboat Inspector of Nova Scotia, by the Government of Canada; in 1862 he was appointed Steamboat Inspector for the Province of Prince Edward Island, by the Prince Edward Island Government and Commission, signed by the Royal Governor of Prince Edward Island, then a separate colony; and when Prince Edward Island entered the Dominion in 1873, Mr. Smith was appointed Steamboat Inspector for the Maritime Provinces of the Dominion of Canada; in the year 1872 he was chosen Deputy Chairman of the Board of Steamboat Inspectors by the Government. After thirty-three years of continual employment as Inspector of Steamboats, Mr. Smith retired from official life, February, 1886. His official life was a very busy one, as he had a very large district to travel over, reaching from Dalhousie, N. B., to North Sydney, C. B., and including Prince Edward Island; and as nearly every sea and river port has its steamboat, the reader can imagine the amount of travelling he yearly had to do, outside of extra trips required. Beside this, the Government of Canada often required his opinion on fog alarm and marine station repairs, which took him to many of the remote islands and places in the Maritime Provinces.

The subject of the foregoing sketch has worked for over fifty years in a mechanical trade or profession, and is at present a Consulting Engineer, St. John, N. B., Canada; at the time of applying for superannuation, was the oldest Inspector in Eastern North America, and by nine years the longest in service in Canada.

The following is a partial list of the private mechanical works with which he has been in some way connected in a professional manner:

Seagoing side-wheel steamer "Princess of Wales," of Charlottetown, P. E. I., superintended and prepared plans for boiler and engine, furnished and fitted for sea; built for the Prince Edward Island Steam Navigation Company. "Heather Bell," side-wheel steamer, prepared plans for the hull, engine and boiler, superintended during the building; built for E. Lunt & Sons, for the St. John River service; also put in the first compound engine, an inclined and oscillating cylinders combined, built in New Brunswick for above steamer. Side-wheel steamer "Heather Bell," of Prince Edward Island, passenger steamer, inclined low pressure engine; this steamer proved fast, making fourteen knots per hour.

"Blue Bird," a side-wheel low pressure steamer, beam engine, built for the British Government, for service at Bermuda Islands, for the conveyance of troops, etc.; built by Mr. Smith, under the inspection of British naval officers.

Steamship "Alpha," Summerside, P. E. I., high pressure engine, for freight business, superintended hull, engine and boiler, etc., prepared plans, etc.

Paddle ferry steamer "Frank," for Island Hotel Company, Summerside, P. E. I., plans, etc., superintended building. Paddle ferry steamer "Southport," for Prince Edward Island Provincial Government, specification, plans, etc.

Steamship "Albert," St. John, N. B., plans, and superintended building. Steamship "Earl Dufferin," plan for engine and boiler. Stern wheel steamer "Florenceville," plans, and superintended engine, boiler and hull; John Retallick's, sr., model, speed ten knots an hour; runs on the Upper St. John River.

Inspector of gas and illuminating power of the City of St. John for fourteen years; also tested coal and oil for the Canadian Government for a number of years. Was chosen and appointed as an expert to make experiments on coal oil before a select committee of the House of Assembly, of the Province of New Brunswick, for the purpose of enacting a law for to govern the sale of coal oil.

Improved Foulis' application of the steam whistle to fog alarms, and made plans and specification for house, engine and boiler, from his own design, and invented an improved whistle for these alarms. Furnished information to Gen. Deuanne, Engineer Naval Department of United States coast service, in relation to the constructing of fog alarms; Gen. Deuanne and Inspector Staples, of Portland, Maine, U. S., visited St. John, and interviewed Mr. Smith on this matter. Built by contract a large and powerful fog alarm for Government of Newfoundland for erection at Cape Race, constructed by Fleming & Sons. Superintended and made plans for over nineteen fog alarms for the Government of Canada. Made plans and specifications for the lightships built for the Government of Canada, that had steam fog alarms on them.

Erected the No. 1 dioptric light at Cape Sable, Seal Island, and also a No. 2 at Machias, Seal Island. Made the drawing and specification for a bronze (gun-metal) screw, twelve feet diameter, weighing 9,000 pounds, for steamship "Northern Light," a Government steamer employed in the winter service when the ice will not allow the regular steamers to run; this screw proved a great success, and is now perfect and still in use.

The Maritime Provinces contains 119 steamers, more or less (1885), and at one time as high as 126 steamers; all of which have to be inspected at least once a year. This yearly work, combined with the position of Deputy Chairman Board of Steamboat Inspection, and to look after any local marine works, were faithfully and successfully carried out by Mr. Smith, until increasing years made it necessary for him to seek a less arduous life.

45 VICTORIA—CHAP. 35.

AN ACT TO AMEND AND CONSOLIDATE THE ACTS RESPECTING THE INSPECTION OF STEAMBOATS, AND THE EXAMINATION AND LICENSING OF ENGINEERS EMPLOYED ON THEM.

(Assented to 17th May, 1882.)

For the greater security of life and property on board steamboats navigating the waters of the Dominion of Canada, or owned or registered in the Dominion of Canada, and departing from or arriving at any port or place in the Dominion of Canada: Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:

EXTENT AND APPLICATION OF ACT.

1. This Act may be cited for all purposes as "The Steamboat Inspection Act, 1882," and shall extend and apply to the whole Dominion of Canada, including Manitoba and the North-West Territories and Keewatin.

2. This Act shall be construed as being passed in amendment of the Act thirty-first Victoria, chapter sixty-five, intituled "An Act respecting the Inspection of Steamboats, and for the greater safety of passengers by them," as amended by the Acts thirty-second and thirty-third Victoria, chapter thirty-nine; thirty-sixth Victoria, chapters seven and fifty-three; thirty-seventh Victoria, chapter thirty; fortieth Victoria, chapter eighteen, and forty-fourth Victoria, chapter twenty-one, which are hereby superseded and repealed (except as hereinafter provided), with every other Act, enactment or provision inconsistent with this Act,—and as being a consolidation of the amendments hereby made with those portions of the said Acts which are herein re-enacted, and of such Orders in Council made under them as are herein incorporated, all

which shall be construed as declaratory of the existing law: and all appointments made and all things lawfully done under the provisions of law then in force, shall remain valid, unless and until it is otherwise ordered by or under this Act, and all proceedings commenced under them may be continued and completed, as if this Act had not been passed, only the amendments hereby made having effect as new law.

3. In this Act the word "steamboat" includes any vessel used in navigation or afloat on navigable water, and propelled or moveable wholly or in part by steam; the word "owner" includes the lessee or charterer of any such vessel; and the word "year" means the calendar year, commencing on the first day of January, and ending on the thirty-first day of December.

4. This Act shall not apply to steamboats belonging to Her Majesty the Queen, nor to steamboats registered in Great Britain and Ireland or in any foreign country, and plying between any port or place in the Dominion of Canada and any port or place outside of the Dominion of Canada:

(2.) And all steam yachts, used exclusively for pleasure or private use without hire or remuneration of any kind, all tug boats, all steamboats carrying freight only (hereinafter called freight boats) and under one hundred and fifty tons gross, and all steamboats used only for fishing purposes or the carrying of fish, and under one hundred and fifty tons gross, and steam dredges and elevators or vessels of like kind, shall be exempt from the requirements of this Act,—except as regards the inspection of their boilers and machinery, to which they shall be subject at least once in each year, and oftener if required, under the same provisions and penalties for neglect as other steamboats,—and except also as to the obligation to carry one life buoy hereinafter imposed on all steamboats.

5. The Governor in Council may direct that any steamboat not registered in the Dominion of Canada, but employed in the Dominion of Canada in carrying mails, passengers or troops, shall be subject to the provisions of this Act.

APPOINTMENT AND QUALIFICATION OF INSPECTORS.

6. The Governor in Council shall, from time to time, appoint at each of such places, and to act respectively within such local limits, as he may find advisable, within the Dominion of Canada, a skilled person or skilled persons competent to inspect the boilers and machinery employed in steamboats, who shall not be interested in the manufacture

of steam engines, boilers or other machinery belonging to steamboats, and whose duty it shall be to make such inspection as hereinafter prescribed, and to give to the owner or master two of the certificates of such inspection,—and also a skilled person or skilled persons competent to inspect the hulls and equipment of steamboats, who shall not be interested in the building or construction of hulls of steamboats, or of any article or thing hereinafter mentioned as part of the equipment required by this Act for steamboats, or properly belonging to or connected with such equipment according to the intent of this Act, and whose duty it shall be to make such inspection, and to give triplicate certificates of such inspection:

2. In this Act the expression "boilers and machinery" includes the steam engine or engines, and every part thereof or thing connected therewith, employed in propelling the steamboat, and any donkey or pony engine used on board, and the boiler or boilers for supplying steam thereto, and the furnaces, chimneys, flues, safety and blow-off valves, gauges, braces, stays, pipes, steam pumps, and all other apparatus and things attached to or connected therewith or used with reference to any such engine or under the care of the engineer; and the expression "hull and equipment" includes the hull and every part thereof, masts, sails and rigging when the steamboat carries them, life-boats and other boats and the tackle and apparatus for lowering or hoisting them, the apparatus, other than steam fire engines, for preventing or extinguishing fires, anchors and cables, windlasses and capstans, fire buckets, compasses, axes, lanterns, and all other articles and things necessary for the navigation and safety of the steamboat and not under the care of the engineer: the word "Inspector," in any provision in the following sections, means a person appointed to inspect the "boilers and machinery" of steamboats, when and so far as such provision applies to anything included in that expression, or a person appointed to inspect the "hulls and equipment" of steamboats, when and so far as the provision applies to anything included in the expression last mentioned; the word "boiler" means a boiler of or intended for a steamboat, and includes boilers when the steamboat has more than one, and the word "boilers" means "boiler" when she has only one; and the word "hull" includes the equipment unless the context is inconsistent with such construction; and the word "certificate" means one of the duplicates or triplicates of the certificate given by the inspectors or inspector, as the case may be.

7. No person shall be appointed an inspector of boilers and

machinery of steamboats unless nor until he has passed a satisfactory examination before the Board of Steamboat Inspection, as to his knowledge on the subject of boilers and machinery of steamboats, and the working of the same; or an inspector of the hulls and equipment of such vessels, unless he has passed a satisfactory examination as to his competency for the office, before a board of three practical shipbuilders to be appointed by the Governor in Council, or is a certified surveyor of a recognized society for the classification of shipping; nor shall he be appointed an inspector for either purpose unless he has received from the chairman of the Board, or from the said practical shipbuilders (as the case may be) a certificate in writing that he has satisfactorily passed such examination, or is a certified surveyor as aforesaid:

(2.) Provided always, that all inspectors appointed before the passing of this Act shall continue in office as inspectors of boilers and machinery until removed under this Act:

(3.) Every such inspector, before entering upon his duties as such, shall take and subscribe an oath, before any person duly authorized to administer an oath, well, faithfully and impartially to execute the duties assigned to him by this Act.

(8.) The inspectors shall form a Board, to be called the "Board of Steamboat Inspection," of whom the Governor shall name the chairman; three of the members shall form a quorum, and the chairman shall have the right to vote, and in case of an equal division he shall also have a casting vote; and the minutes of the proceedings of the Board shall be kept by him:

(2.) The Board shall meet at least once every year at such place as they may agree upon, and may make rules and regulations for their own conduct, and for the uniform inspection of steamboats, the selection of ports of inspection, and granting licenses to engineers, and for such other purposes as may be necessary under this Act, and may, from time to time, repeal, alter or add to such rules and regulations or make others in their stead; and such rules and regulations shall come into force after they have been approved by the Governor in Council, but not before; and copies of the minutes of the proceedings of the Board, certified by the chairman, shall be transmitted to the Minister of Marine and Fisheries; provided that such rules and regulations made before this Act comes into force shall remain in force until repealed or amended under it:

(3.) Provided always, that in the Provinces of Manitoba and British Columbia, and in the North-West Territories and the

District of Keewatin, the Minister of Marine and Fisheries may, if and when he sees fit, dispense with the appointment of an inspector of hulls and equipment; and in such case and in case of the non-appointment of such inspector in any inspection district, or of vacancy in the office therein, the said Minister may, by departmental order, assign the duties of such inspector to the inspector of boilers and machinery, or such other person as he may temporarily employ,—who shall then and so long as such order remains in force, have all the powers and perform all the duties hereby assigned to the inspector of hulls and equipment, under the like obligations and like penalties in case of default,—the forms of certificate being altered to suit the case.

INSPECTION GENERALLY.

9. The chairman of the Board of Steamboat Inspection may, at any time, inspect or examine the hull, boiler and machinery of any steamboat, and if he suspects any inspector of having neglected his duty in relation to such steamboat, he may call a meeting of the Board to investigate the case; and the result of every such investigation shall forthwith be communicated in writing to the Minister of Marine and Fisheries, for the information of the Governor in Council.

10. The master or owner of every steamboat liable to inspection under this Act, shall cause the boiler and machinery and the hull and equipment thereof, to be inspected at least once every year, and shall deliver to the chief officer of Customs at the port where such inspection is made, or at which such steamboat shall arrive next after such inspection, where it has not been made in such port, one of the certificates thereof; and for every neglect to cause such inspection to be made, and a certificate thereof to be delivered to the proper officer of Customs, such master or owner shall incur a penalty of four hundred dollars, and such steamboat shall be liable for the same and chargeable therewith; and every such certificate unless sooner revoked, shall be good for a period of twelve months from the date thereof, or for such less period as may be stated by the inspector in the certificate.

11. The master, owner or engineer of every steamboat, or the person in charge thereof, shall at the earliest opportunity after the occurrence of any event whereby the hull, or the machinery, or boiler thereof, or any part of any or either of the same, is in any material degree injured, strained or weakened, report such occurrence to the inspector by whom

the same was last inspected, or to the proper inspector at the port or place where the steamboat is, or first arrives after such event occurs; and in case of omission to give such notice the owner of the steamboat shall forfeit to Her Majesty two hundred dollars for every day during which such omission continues; and if the injury be to the machinery or boiler or any part of the same, the license of the engineer shall be revoked.

12. Any inspector may, at all times when inspecting, visiting or examining any boilers and machinery or the hull of any steamboat, ask of any or all of the owners, officers or engineers of such steamboat, or other person on board thereof, and in charge or appearing to be in charge of the same, or of the boiler or machinery thereof, such pertinent questions concerning the same, or concerning any accident that may have happened thereto, as he may think fit; and every such person shall fully and truly answer every such question so put to him respectively, to the best of his knowledge and ability; and every person refusing to answer or falsely answering such question, or preventing any such inspection or obstructing any inspector in the same, shall, by so acting, incur a penalty of forty dollars.

13. Any inspector of steamboats is hereby empowered to demand of the owner or master of any steamboat being inspected by him, the production of the certificate of registry of such steamboat; and it shall thereupon be the duty of such owner or master to produce and exhibit the same to such inspector.

14. When the inspector finds it necessary to open up the hull of a vessel for the purpose of examining her condition, the expense incurred thereby shall be chargeable to the owner of such vessel.

15. The inspector may require that the engine and machinery under inspection by him, be put in motion; and any inspector shall be carried free of expense on any steamboat which he shall desire to inspect while under way, and during such period as may be necessary for such inspection, and for his return to the port at which he embarked on such steamboats for such purpose, or for his disembarkation at any port at which such steamboat touches on her voyage.

16. If the inspector who inspects any steamboat in the manner required by this Act, approves the hull and equipment of such steamboat, he shall sign a certificate according to the form A in the schedule of this Act, and triplicates of such certificate, signed by the inspector of hulls and equipment

shall be delivered by him to the inspector of boilers and machinery for the same district, who, if he has then inspected and approved the boilers and machinery of the steamboat and has also satisfied himself that the certificate of the inspector of hulls and equipment is true and correct as to the said equipment, and as to the number of passengers the steamboat may lawfully carry, and as to all the particulars mentioned in the said form, and that the equipment is sufficient and in accordance with the requirements of this Act, shall sign the certificate in triplicate and deliver two of such triplicates to the owner or master of the steamboat,—who shall deliver one triplicate to the chief officer of Customs as aforesaid, and the other he shall cause to be posted up, framed and protected by glass, in some conspicuous part of the steamboat for the information of the public; and the inspector of boilers and machinery shall retain the other triplicate for the purposes of this Act:

(2). Except that, if the steamboat is one of which the boiler and machinery only is subject to inspection under this Act, the inspector of boilers and machinery shall sign a certificate in the form B in the said schedule, in duplicate, and deliver the duplicates to the master or owner of the steamboat, who shall deliver one to the chief officer of Customs and cause the other to be posted up in some conspicuous part of the steamboat for the information of the public:

(3). Any matter in dispute arising under this or any other sections of this Act, between an inspector or the Board of Inspection and the master or owner of any steamboat, and also any dispute between an inspector or the Board of Inspection and an engineer, may be referred by either party to the Minister of Marine and Fisheries, who shall finally decide the same:

(4). Each inspector shall keep a register of the inspections and certificates made and granted by him, in such form and with such particulars respecting them as the Inspection Board shall, from time to time, require, and shall furnish copies thereof to the Board when required.

INSPECTION OF BOILERS AND MACHINERY.

17. Any inspector may, whenever he deems it necessary so to do, and some one of them shall, at least once in every year, subject the boiler of every steamboat to a test by hydrostatic pressure, and shall satisfy himself by examination and experimental trials, that such boiler is well made, of good and

suitable material; the limit of such pressure shall not exceed one hundred and fifty pounds to the square inch in the case of a boiler made of iron plates, or one hundred and ninety pounds to the square inch in the case of a boiler made of steel plates; and the owner of the steamboat shall provide the necessary hand-pump and apparatus for such test, to be worked by the crew of the steamboat; and no inspector shall make or deliver to the owner or master of any steamboat, any such certificate as is mentioned in the sixteenth section of this Act, without having first subjected the boiler of such steamboat to such test by hydrostatic pressure:

(2). Before subjecting a boiler to a test by hydrostatic pressure, it shall be opened up for inspection, the man-hole doors and mud-plates removed, and the outside and inside of the boiler cleaned, the furnace grates removed and the furnace swept out clean, so that satisfactory and efficient inspection can be made; when bulkheads are so placed as to prevent a close examination of the plates of the boiler, they shall be removed; the owner or master of the steamboat shall see that these requirements are complied with before applying for inspection:

In any case in which the test is not satisfactory, the defects must be made good and the boiler re-tested satisfactorily, before a certificate shall be granted; and—

When the outside of the bottom of a boiler cannot be otherwise perfectly inspected, the boiler shall be lifted for inspection once at least in every four years:

(3). In subjecting boilers made of iron plates to the hydrostatic test aforesaid, the inspector shall assume one hundred pounds to the square inch as the maximum pressure allowable as a working power for a new boiler forty-two inches in diameter made of the best refined iron, at least one-quarter of an inch thick, in the best manner and of the quality herein required,—and shall rate the working pressure of all iron boilers, whether of greater or less diameter, according to this standard; and in all such cases the test applied shall exceed the working pressure allowed, in the ratio of one hundred and fifty pounds to one hundred, using the water in such tests at a temperature not exceeding sixty degrees Fahrenheit:

(4). In subjecting boilers made of steel to the hydrostatic test aforesaid, the inspectors shall assume one hundred and twenty-five pounds as the maximum pressure allowable as a working power for a new boiler forty-two inches in diameter, made in the best manner, of the best quality of steel plates, at least one-quarter of an inch thick, with all the rivet holes drilled in place, the plates being then taken apart and the burrs removed, the longitudinal seams in the shell being fitted with double butt steel straps cut across the grain of the plate, and each of five-eighths the thickness of the plates they cover, and all the seams being at least double-rivetted and having at least seventy per cent. of the strength of the solid plate, and all the flat surfaces stayed in the best manner and all the seams double-rivetted,—and they shall rate the working pressure of all steel boilers so made, whether of greater or less diameter, according to this standard; and in all such cases the test applied shall exceed the working pressure allowed for such boilers in the ratio of one hundred and ninety pounds to one hundred and twenty-five pounds, using the water in such tests at a temperature not exceeding sixty degrees Fahrenheit:

(5). But if the inspector is of opinion, that any boiler, whether made of iron or steel plates, by reason of its construction or material, will not safely allow so high a working pressure as that hereinbefore specified for each such description of boiler respectively, he may, for reasons to be stated specifically in his certificate, fix the working pressure of such boiler at less than two-thirds of the test pressure:

(6). And these rules shall be observed in all cases, unless the proportion between such boilers and the cylinders, or some other cause, renders it manifest that their application would be unjust,—in which case the inspector may depart from these rules if it can be done with safety; but in no case shall the working pressure allowed exceed the proportion hereinbefore mentioned, as compared with the hydrostatic test:

(7). The external working pressure to be allowed on circular furnaces and flues subjected to such pressure, when the longitudinal joints are welded or made within a butt strap, shall be determined by the following formula:

The product of 90,000 multiplied by the square of the thickness of the plate in inches,—divided by the length of the flue or furnace in feet plus 1, multiplied by the diameter in inches,—will be the allowable working pressure per square inch in pounds,—provided it does not exceed that found by the following formula,—

The product of 8,000 multiplied by the thickness of the plate in inches, divided by the diameter of the furnace or flue in inches, will be the allowable working pressure per square inch in pounds,—

The length of the furnace to be used in the first formula being the distance between the rings, if the furnace is made with rings; and that one of the two formulæ which gives the lowest pressure being the one by which the inspector shall be guided:

(8). On flat surfaces the allowable working pressure shall not exceed six thousand pounds to each effective square inch of sectional area of the stays supporting it; the pressure to be allowed on plates forming flat surfaces shall be that found by the following formula:

$$\frac{C\times(T+1)^2}{S-6} = \text{Working pressure in lbs. per sq. inch, where—}$$

T=Thickness of plate in sixteenths of an inch;
S=Surface supported in square inches;
C=100; but when the plates are exposed to the impact of heat or flame, and steam only is in contact with the plates on the opposite side, C is to be reduced to fifty:

(9). In order to satisfy himself as to the strength and condition of a boiler, the inspector may, if he deems it necessary, order holes to be cut in it, and may also demand that such information be furnished him as to the interior construction of the boiler as will enable him to judge correctly of its strength:

(10). In no case shall a certificate be granted for a boiler when drift pins have been used in bringing the holes in the sheets together:

(11). Man-hole openings must be stiffened with compensating rings of at least the same effective sectional area as the plate cut out, and in no case shall such rings be of less thickness than the plates to which they are attached; all openings in the shells of cylindrical boilers shall have their short axes placed longitudinally:

(12). When bars or angle irons are used for sustaining the crown sheet of the furnace of a boiler, three-fifths of the working pressure allowable upon the crown sheet shall be sustained by hanging stays from the shell of the boiler attached to the crown sheet:

(13). Donkey boilers on steamboats shall be provided with two safety-valves, one of which may be locked up:

(14). Boilers in which the longitudinal seams in the cylindrical shell are single rivetted, in place of double-rivetted, shall be subject to a reduction in the working pressure allowable for a boiler made in the best manner (as prescribed by sub-sections three and four of this section), and the limit of pressure in boilers so made shall not exceed eighty pounds to the square inch in place of one hundred pounds or one hundred and twenty-five pounds, as mentioned in sub-sections three and four of this section.

18. No boiler made and placed on board after the passing of this Act shall be made of boiler plate, whether iron or steel, which has not been stamped with the mark or name of the maker thereof; and no certificate shall be granted with respect to any boiler made wholly or in part of plate not so marked: and before a certificate shall be granted with respect to any boiler, a declaration on oath by the maker of the boiler, stating the name of the maker of the plates, their quality, and the quality of all materials used in the construction thereof, shall be furnished to the inspector,—which oath may be taken before any Justice of the Peace in Canada, or before a Notary Public, and certified under his official seal, if taken out of Canada: Provided always, that in any case where such declaration on oath by the maker of the boiler cannot be obtained owing to the death of the maker, or from other cause deemed sufficient by the inspector, the affidavit of two practical boiler-makers who shall examine the boiler and report upon the quality of the materials in it and its workmanship and strength, shall, if satisfactory to the inspector inspecting the boiler, be deemed sufficient in lieu of such declaration by the maker of the boiler:

(2). During the construction of every boiler made in Canada, the maker of such boiler shall notify the inspector of the district in which it is being made, that it is open to his inspection, and shall, at all times during such construction, allow the inspector access to such boiler:

(3). No boiler or pipe shall be approved is made in whole or in part of bad material, or is unsafe in its form, or dangerous from defective workmanship, age, use or any other cause.

SAFETY-VALVES, STEAM GAUGES, ETC.

19. Every inspector, when inspecting, visiting or examining the boiler or machinery of any steamboat, shall satisfy himself that the safety-valves attached thereto are of suitable dimensions, sufficient in number, well managed and in good working order, and only loaded so as to open at or below the certified working pressure; and he may, if he thinks proper, order and cause one or more of such safety-valves, which together shall be of sufficient dimensions to discharge all the steam the boiler can generate, and of such construction as he approves, to be locked up and taken wholly away from the

control of the engineer when the steam is up; but this provision does not imply that the engineer is not to have access to the safety-valves when the steam is not up, but on the contrary he shall see that they are kept in working order, and the master of the steamboat shall see that the engineer has access to them for that purpose, and keeps them in proper working order:

(2). The boiler-cocks and valves attached to the boilers, shall be substantially made, and in no case shall they be attached to the boiler by screwing into the plate, unless, as an additional security, nuts and flanges be used in addition to such attachment:

(3). No valve, under any circumstances, shall, at any time, be so loaded, or so managed in any way, as to subject a boiler to a greater pressure than that allowed by the inspector at the then last inspection thereof:

(4). The lock-up valves shall be of a construction, approved by the Board of Steamboat inspection,—such valves to be tested and proved by an inspector before use; and no inspector shall grant a certificate to any steamboat unless the boiler, or each boiler, if more than one, of such steamboat be provided with two safety-valves, one of which shall be locked up and one open:

(5). Every safety-valve made or placed on board after the passing of this Act, or attached to a boiler made after that time, must have a lift equal to at least one-fourth of its diameter; the openings for the passage of steam to and from the valve must each have an area not less than the area of the valve, as shall also the waste steam pipe, and the valve box must have a waste water pipe; if the lever of a lever safety-valve is not bushed with brass the pin must be of brass,—iron and iron working together must not be allowed; every such safety-valve must be fitted with lifting gear so that it can be worked by hand, either from the engine room or the fire-hold, or by the master or person in charge on deck; every such safety-valve must be so attached to the boiler, that the valve chest shall be as close to the boiler as possible.

20. The area of any locked safety-valves or the joint areas of any locked safety-valves to any boiler, made or placed on board after the passing of this Act, shall not be less than half a square inch for each square foot of grate surface in or under the boiler.

21. Whenever the engine of any steamboat is stopped for any purpose, the engineer or the master or person in charge of such steamboat shall open the safety-valve, so as to keep

the steam in the boiler down to ten pounds below the pressure limited by the inspector's certificate if the engine be a high pressure engine, and to five pounds below the pressure limited as aforesaid if the engine be a low pressure engine, under the penalty of two hundred dollars for every contravention of this provision.

22. In a conspicuous and easily accessible place, in each steamboat, there shall be a steam gauge properly constructed and open to the view of all passengers and others on board such steamboat, and showing at all times the true pressure of the steam in the boiler thereof.

23. And if any master or engineer of any steamboat at any time allows the pressure of steam, to which the boiler of such steamboat is subjected, to exceed that limited by her certificate, or alters or conceals or otherwise deals with the said steam-gauge, so as to prevent the real pressure of steam from being seen and ascertained by any passenger, he shall thereby incur a penalty of two hundred dollars for every such offense.

24. The steam-gauge required by this Act to be open to the view of all passengers and others on board any steamboat, shall be that known as "The Bourdon Gauge," or shall be of such construction and shall be put in such place and position, as the inspector inspecting, visiting or examining such steamboat shall, from time to time, direct.

25. Each boiler of every steamboat shall be provided with a suitable water-gauge, capable of showing the water level within each boiler at all times; and all steamboats navigating in brackish or salt water, shall be provided with surface blow-off valves, such as are commonly used on board seagoing steamboats.

SAFETY BILGE INJECTION-PIPE.

26. Every steamboat carrying passengers and having a condensing engine, shall be provided with a bilge injection-valve and pipe of suitable dimensions, leading from the floor-frames of the steamboat into the condenser of the engine.

BOATS AND LIFE PRESERVERS TO BE CARRIED BY STEAMERS.

27. No steamboat of the registered tonnage of one hundred tons or upwards shall depart by sea from any port or place within the Dominion of Canada, or depart from any port or place, on either of the lakes Memphremagog, Ontario, Erie, Huron, Simcoe or Superior, or on the river St. Lawrence, or on the river Ottawa, or St. John, or on any lake or river in

Manitoba, British Columbia, or the North-West Territories, or the District of Keewatin, which is at any place on the route of such steamer more than one mile in width, with passengers, without having on board or attached to such steamboat, one good and sufficient life boat made of suitable metal, fire-proof, with air-tight metallic compartments at the ends and sides (except as hereinafter provided) according to the directions of the inspector, capable of sustaining, inside and outside, fifty persons, with life-lines attached to the gunwale at suitable distances, or having on board two good and sufficient life boats, with air-tight metallic compartments as aforesaid, each capable of sustaining inside and outside thirty persons, with life-lines attached to the gunwales at suitable distances, and in either case with sufficient oars and other suitable tackle:

(2). The life boat required to carry fifty persons may be considered of sufficient capacity if made of the following dimensions:—

Length of keel, twenty-two feet; breadth of beam from metal to metal, five feet six inches; depth from top of keel to top of gunwale at bottom of row-lock, two feet nine inches:

The life boat required to carry thirty persons may be considered of sufficient capacity if made of the following dimensions:—

Length of keel, eighteen feet; breadth between metal and metal, five feet two inches; depth from top of keel to top of gunwale, two feet two inches.

28. Notwithstanding anything to the contrary contained in the immediately preceding section, the life boat or life boats on board of or attached to any steamboat on any of the voyages of such steamboat, may have air-tight metallic compartments at the sides only, or at the ends only, or shall have them at both ends and sides, according to the directions of the inspector by whom such steamboat was last inspected.

29. No steamboat of any registered tonnage whatever shall depart by sea from any port or place in the Dominion of Canada or depart from any port or place on any of the lakes or rivers mentioned or referred to in section twenty-seven, with passengers, without having on board or attached to such steamboat, a good, suitable and sufficient boat, or good, suitable and sufficient boats, in good condition and properly equipped,—every such boat to be provided with not less than six oars, and other necessary tackle, and to be of sufficient capacity to carry not less than twelve adult persons, exclusive of the crew of such boat, and to be of not less than seventeen

feet length of keel,—and the number of such boats to be in the following proportion to the registered tonnage of such steamboat, that is to say:—

For every steamboat of less than fifty tons, one such boat; for every steamboat of fifty tons and upwards, but less than one hundred tons, not less than two such boats; for every steamboat of one hundred tons and upwards but less than three hundred tons, not less than two such boats, in addition to the life boat above required; for every steamboat of three hundred tons and upwards, not less than three such boats, in addition to the life boat above required.

All such boats shall be hung in separate davits, with lowering apparatus complete and ready for instant lowering: Provided, that in any case where any such steamboat carries two life boats, one of the other boats may be carried on the hurricane deck without davits; the boats shall be kept in good condition, water-tight and ready for immediate use, and masters of steamboats shall detail their crews and exercise them in lowering and handling the said boats at least once a month; when wood is used as fuel in the boilers of high-pressure steamboats, the covers of the said boats shall be made of wood covered with zinc; and every boat shall have the name of the steamboat to which it belongs and of her port of registry legibly painted on her bows and stern.

Provided, that no steamboat employed chiefly in the carriage of freight, when carrying not more than twenty-five passengers shall be required to have on board or attached to such steamboat more than two boats in addition to a life boat.

30 Provided, that the Minister of Marine and Fisheries may authorize the use in individual specified cases, of boats of different dimensions from those specified in sections twenty-seven, twenty-eight and twenty-ninth of this Act, and upon such authorization being granted, it shall be sufficient that boats of the dimensions specified in such authorization be provided and carried on the steamboat to which such authorization relates.

31. Every steamboat employed in the carriage of passengers which shall be used in the navigation of rivers, or inland navigation only, except as specified in sections twenty-seven and twenty-nine of this Act, shall carry not less than two good boats, provided with four oars each, and of sufficient capacity to carry not less than twelve persons with safety, besides the crew, except steamboats confined to the navigation of the river St. John, above Fredericton, the waters in the district of Muskoka, the county of Victoria and the county

of Peterborough, in the Province of Ontario, and the waters of the Ottawa river, and its tributaries above the city of Ottawa, or of lakes or rivers not exceeding one mile in width at any place on the route of such steamboat, which shall carry one good boat of the size and provided as aforesaid; and except also steamboats of less than fifty tons register, which shall carry one good boat of the size and description, and provided in the manner approved of, in each case, by the inspector: Provided always, that steamboats not exceeding one hundred and fifty tons register shall not be required to carry more than one good boat of the capacity above mentioned.

32. Every steamboat to which the twenty-seventh and twenty-ninth sections of this Act apply, shall be provided with sufficient means for lowering from on board safely and expeditiously each boat required by the said sections to be on board or attached to such steamboat, on each occasion on which such boats are so required to be on board of or attached to the same:

(2). Three davits properly constructed and placed shall be considered sufficient for lowering two boats.

33. Every steamboat not employed in the carriage of passengers, and every steamboat to which the twenty-seventh, twenty-eighth, twenty-ninth, thirty-first, thirty-fifth and thirty-eighth sections of this Act do not apply, shall, at all times when the crew thereof is on board, be provided with and have on board or attached to such steamboat in some convenient place, a good, suitable and sufficient boat, or good, suitable and sufficient boats, in good condition and properly equipped, and provided with oars in sufficient number and other necessary tackle, and of sufficient capacity to carry all the crew of such steamboat, and with sufficient means for lowering such boat or boats from on board safely and expeditiously, and also a life-preserver for each one of the crew, and also a number in due proportion to that of the crew, of good and sufficient fire buckets, of metal, leather, or other suitable material, and axes and lanterns, to the satisfaction of the inspector.

34. Sections twenty-seven, twenty-eight, twenty-nine, thirty-one, thirty-five and thirty-eight shall not apply to ferry-boats or tugboats plying elsewhere than on the river St. Lawrence.

35. Every sea-going steamboat and every steamboat on any of the lakes or rivers specified in the twenty-seventh and twenty-ninth sections of this Act, or navigating any bay or bays or arm or arms of the sea in connection with the

Dominion, employed in the carriage of passengers, shall be provided with and shall carry on board on every voyage life-preservers as follows, namely: Each and every such steamboat of the registered tonnage of two hundred tons and upwards, shall be provided with two hundred life-preservers; and each and every such steamboat of the registered tonnage of less than two hundred tons shall be provided with not less than three life preservers for every five tons register; and each steamboat carrying passengers on rivers or inland navigation, except on the lakes and rivers specified in section twenty-seven, of the registered tonnage of two hundred tons and upwards, shall be provided with not less than one hundred life-preservers, and each such steamboat as last aforesaid, of less than two hundred tons register, with not less than fifty life-preservers; and all such life-preservers shall be made of the size and material approved of by the inspector, and shall be fitted with shoulder straps and fastenings suitable for securing the same around the body, under the arms; and each such preserver shall have a buoyancy of sixteen pounds, and shall at all times be kept in some convenient and accessible places in the staterooms or on the deck of such steamboat, under cover and in readiness for the use of passengers, and no steamboat shall proceed to sea or on any voyage without being fully provided in compliance with the requirements of this section: Provided alway, that the maximum number of such life-preservers required on any steamboat shall not exceed two hundred. But in any steamboat, as to which the boat capacity, and the number of life-preservers, together fall short of the number of passengers she is allowed to carry by her certificate, such deficiency shall be supplied by a number of wooden floats, each equal in buoyancy to one cubic foot of seasoned white pine, equal to the number of passengers and crew not provided for in the boats or with life-preservers.

(2). Provided always, that notwithstanding anything in the next preceding sub-section, no steamboat employed chiefly in the carriage of freight, when carrying not more than sixty passengers, shall be required to be provided with or carry on board on any voyage, more than one life-preserver for each passenger, and one life-preserver for each of the crew then on board of such steamboat.

36. A cork jacket, with shoulder straps and waist lines for fastening the same around the body, shall be the form of life-preserver to be used on passenger steamboats.

37. Every steamboat registered in Canada, or to which this Act applies, shall carry at least one life buoy with a

proper heaving line attached, in some convenient place where it can be easily got at for use in case of accident requiring it:

But the Governor in Council may, at any time, order and direct that the other provisions of this Act shall not, or shall not for any time specified in the order, in so far as such provisions extend to the carrying of boats and life-preservers, apply to any ferry boat specially mentioned in such Order in Council, and the Government in Council may order and direct that such other provisions as he may deem advisable with respect to the carrying of boats and life-preservers on such ferry boat, shall be applicable to and shall be enforced in respect of such ferry boat.

PRECAUTIONS AGAINST FIRE.

38. Except as hereinafter provided, every steamboat employed in the carriage of passengers, whether by sea, bay, lake or river navigation, of more than one hundred and fifty tons gross, shall be provided with and have on board, in some convenient place, not less than twenty-five sufficient fire buckets of metal or leather, five axes, and six good and sufficient lanterns approved of by the inspector: Provided always, that passenger steamboats of more than seventy-five and less than one hundred and fifty tons gross shall not require to be provided with and have on board more than twelve fire buckets, and that passenger steamboats of seventy-five tons gross and under, and steam-tugs under one hundred and fifty tons gross, shall not be required to be provided with and have on board more than six fire buckets.

39. Suitable and safe provision shall be made throughout the steamboat to guard against danger from fire; and no combustible material liable to take fire from heated iron or any other heat generated on board any steamboat, in and about the boilers, pipes or machinery, shall be placed at less than six inches distant from such heated metal or other substance likely to cause ignition; and further, when wood is so exposed to ignition, it shall, as an additional preventive, be shielded by some incombustible material, in such manner as to allow the air to circulate freely between such material and the wood: and metallic vessels or safes shall be provided and kept in some convenient place to receive cotton-waste, hemp, and other inflammable substances, which are in use on board:

(2). Provided however, that when the structure of the steamboat is such, or the arrangement of the boiler or machinery is such, that the requirements aforesaid cannot, without serious inconvenience or sacrifice, be complied with, the inspector may allow deviations from the said requirements, if in his judgment it can be done with safety:

(3). But inflammable matter, when carried on any steamboat, shall invariably be stowed away as far as possible from the boiler, and from places where its ignition is possible:

(4). No fire nor any lighted lamp, candle, or other artificial light by which fire may be communicated, shall be allowed in any stateroom of any passenger steamboat, nor in the steerage thereof unless in a locked and glazed lantern.

40. Every steamboat carrying passengers, shall have at least three double-acting forcing pumps, with chambers at least four inches in diameter, two to be worked by hand, and one by steam, if steam can be employed independent of and not worked by the main engine, otherwise, all three by hand,—one whereof shall be placed near the stern, one near the stem, and one amidships, each having a suitable well-fitted hose of at least two-thirds the length of the steamboat, kept at all times in perfect order, clear of freight or other obstructions, with hose coupled and ready for immediate use; each pump and coupling shall be provided with a hose-wrench chained to the same, and each of the said pumps shall be supplied with water by a pipe connected therewith, and passing through the sides of the steamboat, so low as to be at all times in the water when the boat is afloat.

(2). Provided, that in steamboats not exceeding two hundred tons gross (that is engine-room included) two of such pumps (one of which may be the steam-pump) may be dispensed with, and in steamboats of over two hundred tons, but not exceeding five hundred tons gross, one of such hand-pumps may be dispensed with; but in these cases the hose shall be of such length as to reach easily to every part of the steamboat; and in steamboats where only one pump is used, such pump shall be placed where directed by the inspector:

(3). And in cases where an iron tube or tubes equal in diameter to the hose carried by the steamboat, connected with a force-pump or pumps, and extending at least one-half of the length of the steamboat, is or are fixed under the hurricane deck thereof, and provided with nozzles placed at distances of not more than thirty feet from each other or from either end of the steamboat—to which nozzles the hose carried by the steamboat can be readily attached—it shall not be necessary that the hose should be of greater length than will be sufficient to reach from some one of such nozzles to either end of the steamboat: each nozzle shall be provided with a stop valve or stop cock, so that one or more of such hose attachments may be used, as may be required:

(4). In steamboats under one hundred tons gross, one steam pump of suitable size, or if steam cannot be employed, one force-pump of suitable size worked by hand, shall be sufficient:

(5). In steamboats not exceeding two hundred tons gross requiring only one pump, such pump shall be placed aft, unless the space forward is kept free to admit of ready access to the pump and hose, in which case the pump may be placed forward.

41. Every steamboat of more than sixty tons, registered tonnage, carrying passengers, shall also be provided with a steam pony-pump that may be used as a fire-engine, to be worked independently of the main engine; such steam pony-pump shall be placed on the main deck of the vessel, as near as possible to the engine room, convenient to the control of the engineer; and in all cases the pump hose shall be coupled to the pony and hand fire-pumps, ready for immediate use in case of fire.

42. Every steamboat carrying passengers on the main or lower deck, shall be provided with sufficient means convenient to such passengers for their escape to the upper deck, in case of fire or other accident endangering life.

43. On board every steamboat carrying passengers there shall be placed in some conspicuous place, accessible to all the passengers, a copy of this Act, and in every cabin, stateroom and in other conspicuous places about the vessel, a printed paper (to be provided and filled up by the owner or master of the steamboat) showing the number of boats, with their capacity, and also the number of fire-buckets, axes and life-preservers and floats on board of such steamboat, and the method of adjusting such life-preservers to the body, and a statement of the places where such buckets, axes and life-preservers are kept. The name of the steamboat shall be painted or stamped on all the boats, fire-buckets and floats, axes and life-preservers.

44. The Governor in Council may, from time to time, make, alter or repeal rules and regulations requiring steamboats to carry chemical or other fire extinguishers, and prescribing the number of such fire extinguishers to be carried by steamboats of different sizes and classes respectively; and such rules and regulations being published in the "Canada Gazette," as required by this Act, shall, while in force, have effect and be enforced by the inspectors and others as if made

under this Act; and any contravention thereof shall be punishable as an offence against this Act.

ENGINEERS.

45. Any person claiming to be qualified to perform the duties of an engineer in steamboats, shall apply for a certificate to the Board of Inspection, who shall examine, or shall cause an inspector or inspectors to examine and report upon the applicant and the proofs that he produces in support of his claim; and any such examination may be upon oath, which any inspector may administer; and if upon full consideration the Board of Inspection are satisfied that his character, habits of life, knowledge and experience in the duties of an engineer are all such as to authorize the belief that the applicant is a suitable and safe person to be entrusted with the powers and duties of such a station, the said Board of Inspection shall give him a certificate to that effect under the hand and seal of the Chairman, specifying the grade for which he has been found qualified; and the said certificate, except that of a first-class engineer, shall, subject to the above conditions, be renewed yearly, or oftener if applied for, and may be so renewed by the Chairman in the interim between the meetings of the Board; and for every such certificate the applicant shall pay the sum of five dollars and for every renewal five dollars, which shall be paid to the Receiver General, as part of the Consolidated Revenue Fund: Provided, that if the report of the inspector or inspectors certifying the fitness of an applicant, be made at a time when the Board of Inspection is not sitting, it may be sent by such inspector or inspectors to the Chairman or to the deputy Chairman of the Board, who may thereupon grant a certificate to the applicant to be in force only until the then next meeting of the Board; and the fee paid by him shall not be returned if he does not then obtain a certificate from the Board, but if he obtains it he shall not pay any further fee therefor:

(2). But the license of any such engineer may be revoked by the said Board upon proof of negligence, unskilfulness or drunkenness, or upon the finding of a coroner's inquest, and may also be revoked by the Board for any other cause, provided such other cause be deemed sufficient by the Minister of Marine and Fisheries, and certified as such by him:

(3). It shall not be lawful for any person to keep watch as engineer on any passenger steamboat or on any freight steamboat over one hundred and fifty tons gross, who does not hold a certificate either from the Board or from the Chairman as provided by this Act:

(4). It shall not be lawful for any person to act in the double capacity of engineer and master on any steamboat.

46. Engineers shall be classified according to the following grades:

First-class engineers,
Second-class engineers,
Third-class engineers:

(1). A first-class engineer shall be qualified to take charge of any steamboat:

(2). A second-class engineer shall be qualified to take charge of any freight steamboat, or of any other steamboat, except a seagoing passenger steamboat of more than one hundred nominal horse-power:

(3). A third-class engineer shall be qualified to take charge of any passenger steamboat of less than thirty nominal horse-power, or of any freight steamboat except a seagoing steamboat of more than one hundred nominal horse-power:

(4). Persons who hold certificates as first-class assistant engineers, or limited certificates as competent to take charge of passenger steamboats for the year one thousand eight hundred and eighty-two, may, at any time after the passing of this Act, exchange them for certificates as third-class engineers on payment of a fee of five dollars, which shall be paid to the Receiver General as part of the Consolidated Revenue Fund.

47. It shall not be lawful for any person to employ another as engineer, or for any person to serve as engineer, on any passenger steamboat, or on any freight steamboat of over one hundred and fifty tons gross, unless the person serving or employed as engineer is licensed by the said Board, for the grade in which he is to be employed, except as herein provided; and any person so offering shall incur a penalty of one hundred dollars: Provided however, that if a steamboat leaves a port with a complement of engineers, and on her voyage is deprived of their services, or the services of any of them, without the consent, fault or collusion of the master, owner or any one interested in the steamboat, the deficiency may be temporarily supplied until others licensed can be obtained.

Rules for the guidance of Inspectors of Steamboats examining Engineers.

48. No person shall be qualified for a third-class engineer's certificate who is not over twenty-one years of age or who has not served an apprenticeship of not less than three years in a marine steam engine shop, and been employed on the making and repairing of such engines—or if he has not served such apprenticeship, he must prove that he has been employed for not less than three years as a journeyman mechanic in some workshop, on the making and repairing of such engines; in either case, he must also have served one calendar year in the engine room of a steamboat as engineer on the watch; or he must have served four years at least in the engine room of a steamboat as engineer on the watch; he must be able to give a description of boilers, the methods of staying them, and the requisite strength of their several parts, and must know the means of repairing them; he must know the method of lining the engine, setting the eccentrics and adjusting the slides or valves, and also the cause of any derangement and the means of remedying it; he must write a legible hand and understand the first five rules of arithmetic:

(2). A second-class engineer shall have the qualifications of a third-class engineer with not less than two years' experience as such in the engine room of steamboats of not less than thirty nominal horse-power, as engineer on the watch:

(3). A first-class engineer, shall have the qualifications of a second-class engineer, with not less than three years' experience on one or more steamboats of not less than one hundred nominal horse-power: he must be competent to calculate the thickness of plate required for a boiler of given dimensions and construction to carry a fixed pressure of steam, and also the dimensions and construction of the boiler and thickness of plates being given, the pressure that it may be allowed to carry; he must be able to calculate the strength of its stays, connections, joints and other parts, and the tensile and crushing strength of the materials used in its construction; he must be able to calculate the required capacity of the feed-pump, the area of the safety-valve for a boiler of given dimensions, and the power of the engine from a diagram of its working, and to define the position of the crank and eccentrics as indicated by diagram: he must know the relative volumes of steam and water at different temperatures and pressures, the chemical constituents of coal, its heating and mechanical equivalents, and the quantity of air required for its combustion: he must be competent to make a working drawing of any part of an engine, and explain the operation of the engine or any of its parts in connection with the whole: he must be conversant with surface condensation and the working of steam expansively.

49. Any engineer who feels himself aggrieved by any order or act of an inspector may, within two weeks thereafter, appeal therefrom to the Board of Steamboat Inspection, or to the Chairman when the Board is not sitting, who shall submit the case to the Board at its next sitting; and the Board may confirm, modify or disallow such order or act; and any other person who feels himself aggrieved by any order or act of an inspector, may, within two weeks thereafter, appeal therefrom to the Minister of Marine and Fisheries, who may confirm, modify or disallow such act or order.

INSPECTION FEES.

50. The owner or master of every steamboat in the Dominion of Canada, shall pay yearly, and every year, a rate or duty fixed by the Governor in Council, and not exceeding ten cents for every ton gross which such steamboat measures; and the owner or master of every passenger steamboat exceeding one hundred tons gross, shall pay an inspection fee of eight dollars for each inspection made imperative by this Act; and the owner or master of any passenger steamboat of one hundred tons and less, or of any other steamboat, shall pay an inspection fee of five dollars for each inspection made imperative by this Act:

(2). And for the purposes of this section every ton of the gross tonnage of a steamboat shall be reckoned, and no allowance or deduction shall be made for the space occupied by the engine room:

(3). The amount of such rate or duty and inspection fee or fees shall, in each case, be paid to and received by the chief officer of Customs, at some one of the ports in the Dominion of Canada, who shall account for and pay over the same to the Receiver General for the Consolidated Revenue Fund, at such times and in such manner as the Governor in Council, may, from time to time, direct.

51. No inspector shall make or deliver a certificate respecting any steamboat under this Act, unless the receipt of a chief officer of Customs for the rate or duty payable in respect of such steamboat for the then current year, has been produced and shown to him, nor unless he is satisfied, by

careful examination, that all the conditions and requirements of this Act have been fulfilled and complied with, by and in respect of such steamboat; and every inspector shall report to some chief officer of Customs any case of omission to pay such rate or duty, or of omission to apply for such inspection as aforesaid, for more than one year from the date of the then last inspection, or of refusal to submit to inspection at any time, which in any way or at any time comes to his knowledge.

52. Each chief officer of Customs shall demand of the owner or master of every steamboat which he may have reason to think has not been inspected as required by this Act, or in respect of which he may have reason to think the rate or duty mentioned in section fifty of this Act is due and unpaid, the exhibition of the receipt and certificate in that behalf, appertaining to such steamboat; and if such receipt and certificate, as aforesaid, to his satisfaction, are not produced, then such chief officer shall seize and detain such steamboat until the same are produced and exhibited, and any penalty incurred and lawfully imposed in respect of such steamboat under the provisions of this Act has been paid in full; and in default of payment, such chief officer shall sell such steamboat for the payment of such rate or duty or penalties, in the usual manner, and shall deal with the proceeds as if the penalties were incurred for violation of the Customs laws.

PASSENGERS.

43. The inspectors shall, in their certificate, prescribe the number of cabin or steerage or other passengers, that may be carried by any steamboat inspected by them having regard to the dimensions or tonnage thereof, or both, or otherwise howsoever—subject to appeal to the Minister of Marine and Fisheries, whose decision shall be final; and if such decision differs from that of the inspectors, they shall alter their certificate accordingly.

54. Every inspector may, at any time, visit, within the limits assigned to him, any steamboat, and inspect and examine the same, and if he considers such steamboat unsafe or unfit to carry passengers, he shall report thereon to the Minister of Marine and Fisheries, who may direct that such steamboat shall not be used or run until permitted by the inspector, who shall have made such report, or by order of the said Minister; and any steamboat run or used in contravention of an order of the Minister shall be liable to forfeiture

and to seizure by the chief officer of Customs at any port, and to sale, in the same way and under like provisions as goods liable to forfeiture for non-payment of duties.

55. The master or owner of any steamboat in which a greater number of passengers than that allowed by her certificate is, at any time, carried, shall be guilty of an offence against this Act and shall, for each such offence, incur a penalty not exceeding five hundred dollars and not less than fifty dollars—to be recovered and appropriated in the manner provided by section sixty-six of this Act.

56. The master or person in charge for the time being of any steamboat, who shall, wilfully or negligently at any time, allow to be carried, on board such steamboat, a greater number of passengers than that permitted by her certificate, shall be guilty of a misdemeanor—and upon conviction thereof shall be imprisoned for two years in a penitentiary, or for a less term in any other prison or place of confinement, or shall be subject to a fine not exceeding five hundred dollars, or shall suffer both fine and imprisonment within the above defined limits, as the court may order.

57. No tugboat shall be employed to tow any barge, or any boat, bateau, scow or undecked vessel having passengers on board, unless such vessel has been inspected by an inspector of hulls and equipment, and by him certified as provided in the Schedule C, hereunto annexed, to be fit and properly equipped to carry passengers on the waters on which she is so towed; and no such vessel shall, while so towed, have on board a greater number of passengers than she is certified as being fit to carry safely; and for any contravention of this provision, the master and the owner of the tugboat, and the owner and person in charge of such barge, boat, bateau, scow, or vessel carrying such passengers, shall each incur a penalty not exceeding two hundred dollars, and not less than twenty dollars, to be recovered and appropriated in the manner provided in section sixty-six aforesaid.

MASTS AND SAILS—AND GANG-BOARDS.

58. It shall be lawful for the Minister of Marine and Fisheries, from time to time, by regulations to be made, repealed or altered by him from time to time, and to come into force as provided by the eighth section of this Act, with respect to regulations made by the Board of Inspection, to require that all or any description of steamboats above sixty tons registered tonnage, carrying passengers on the sea coasts of

of the Dominion, or on all or any of the waters of the Domnion, with the exception of that portion of the St. Lawrence between Quebec and Kingston, and of the river connecting Lakes Erie and Huron, and of the waters between Kingston and the head of the Bay of Quinte, and the rivers in the Provinces of Nova Scotia and New Brunswick, and the tributary rivers flowing into the river St. Lawrence, or the lakes west of Quebec, and of any rivers or lakes not exceeding one mile in width on any part thereof on the route of such steamboats, respectively, shall, at all or any seasons of the year, be provided with a mast or masts, and sail or sails, suitable for such steamboats, and to prescribe the dimensions of such mast or masts, and sail or sails respectively.

59. Every steamboat or vessel carrying passengers shall be provided with good and sufficient gang-boards, protected at the sides in a suitable manner against danger to passengers from falling overboard; and the master of such steamboat or vessel shall, on stopping at any wharf or landing-place, cause a gang-board to be firmly secured to the vessel for the safe and convenient transit of passengers; and he shall cause to be affixed to such gangway (in the night time) good and sufficient lights.

60. The owner or occupier of every such wharf or landing place, shall also (in the night time) cause to be shown conspicuously, on such wharf or landing-place, and at every angle or turn thereof, during the whole of the time that any steamboat or vessel is approaching the same or stopping thereat, a good and sufficient light.

61. For the purposes of the two next preceding sections of this Act, the night shall be deemed to extend from one hour after sunset till one hour before sunrise, at all seasons of the year.

62. Any person commanding or having charge of any steamboat, schooner or other vessel, navigating the waters of Canada, and any owner or occupier of a wharf or landing-place, who offends against the fifty-ninth or sixtieth sections of this Act, shall be liable to a penalty of twenty dollars and costs, and in default of payment to imprisonment for a period of not more than twenty days, unless such penalty and costs are sooner paid.

63. The owner or owners of any steamboat or other vessel, or the owner or occupier of any wharf or landing-place, the person commanding or in charge of which neglects to comply with the provisions of the fifty-ninth or sixtieth sections of this Act, shall be liable for all damages sustained by any

person or persons from any accident arising from non-compliance with the provisons of this Act, or during such time as the provisions of this Act are not complied with—such damages to be recoverable at law, before any of Her Majesty's superior courts of common law in the province in which such accident happens.

MISCELLANEOUS PROVISIONS.

64. If any damage to any person or property is sustained in consequence of the non-observance of any of the provisions of this Act, imposing any duty on the owner or master of any steamboat, the owner shall, in all civil proceedings, and the master or other person having charge thereof shall, in all proceedings, whether civil or criminal, be subject to the legal consequences of such default:

And any inspector wilfully, or through any culpable negligence of duty, making or confirming any false statement in any certificate under this Act shall thereby incur a penalty of two hundred dollars.

65. Except when otherwise specially provided, for every contravention in respect of any steamboat in the Dominion of Canada, on any one voyage or trip thereof, of any provision in this Act, or in any Order in Council made under it, the owner or master thereof shall incur a penalty of not more than two hundred and not less than twenty dollars; and any inspector of steamboats is hereby empowered to detain any steamboat on board or in respect of which the provisions of this Act have not been fully complied with, or of which the boilers or machinery or the hull, by reason of any injury or other cause, have, in his opinion, become unsafe; and in case any such inspector gives notice in writing to any chief officer of Customs that any of the provisions of this Act have not been fully complied with in respect to any steamboat, such chief officer of Customs shall not grant any clearance, coasting license or other document for such steamboat, unless nor until he receives the certificate in writing of such inspector, to the effect that such provisions have been fully complied with in respect to such steamboat.

66. All penalties incurred under this Act may, when other provision is not made in the case, be recovered with costs in a summary manner under the Act thirty-second and thirty-third Victoria, chapter thirty-one, in the name of Her Majesty, by any inspector or by any party aggrieved by any act, neglect or omission, on the evidence of one credible witness, who may

be the prosecuting inspector himself, before any Judge of the County Court, Judge of the Sessions of the Peace, Stipendiary or Police Magistrate, or two Justices of the Peace; and in default of immediate payment of such penalty, such magistrate or justices may commit the offender to gaol for any period not exceeding three months, unless such penalty be sooner paid; and one moiety of all penalties recovered under this Act shall be paid to the Receiver General, and shall be, by him, placed to the credit of the Consolidated Revenue Fund, and the other moiety shall belong to the informer unless he is the prosecuting inspector—in which case the whole shall be paid to the Receiver General for the said fund.

67. The Governor may, whenever he thinks fit, order an investigation to be made by any person or persons to be appointed for that purpose, into the cause of any accident involving loss of life on any steamboat; and the person or persons so appointed may summon witnesses and compel their attendance before him or them by the same process as courts of law, and may administer oaths and examine witnesses touching the cause of such accident, and report thereon to the Governor.

68. The Chairman of the Board of Steamboat Inspection shall, at the end of each calendar year, furnish the Minister of Marine and Fisheries with a report of the proceedings of the Board, and a return of all steamboats inspected, and of all penalties collected under the provisions of this Act:

(2). And each inspector shall make monthly returns to the Chairman of the said Board of all steamboats inspected by him, their tonnage and power, with general descriptions of their machinery and hulls, and a statement of the fees collected upon the same.

69. The foregoing provisions of this Act shall come into force and take effect on, from and after the first day of September in the present year, one thousand eight hundred and eighty-two; except that any appointment or arrangement for carrying out this Act may be made before the said day to take effect on and after it.

SCHEDULE A.

Certificate for a steamboat to carry passengers, or a freight steamboat of or over 150 tons gross.

Having examined the hull and equipment of the steamboat *(name)* of whereof is (*or* are) owners, and is master, on this day of A. D. 18 .

The particulars of her gross and register tonnage, as shown on her certificate of registry, being as follows:

	TONS.
Tonnage under tonnage deck........................	
Houses on deck *(naming them)*	
Total gross tonnage....................................	
Deduct for engine room........	
Register tonnage.......................................	

I *(inspector's name)* inspector of hulls and equipment, do hereby certify that her hull is in all respects staunch, seaworthy and in good condition for navigation, that the equipment of the vessel throughout is in conformity with the requirements of *"The Steamboat Inspection Act, 1882,"* the said steamboat having on board, properly placed and in good order for immediate service:

(Number) boats having a carrying capacity for persons; life boats having (together) a carrying capacity for persons; life-preservers; wooden floats; fire buckets; axes; lanterns; chemical fire extinguishers, and one life buoy having a proper heaving line attached: And I declare it to be my deliberate conviction, founded on the inspection I have made, that the said steamboat, as regards her hull and equipment, may be employed on the waters hereinafter specified, without peril to life from any imperfections of or in materials, workmanship or arrangement of the several parts, or from age or use.

And I, *(inspector's name)* inspector of boilers and machinery, do hereby certify that the engine, boiler and machinery of the said steamboat are sufficient and suitable to authorize her being lawfully employed in the carriage of passengers, (*or* as a freight boat, *or* as a ferry-boat, *as the case may be)* without hazard to life on the route on which she is to be placed as hereinafter mentioned; that the engine of the said steamboat is of nominal horse-power, and that her boiler can carry with safety pounds of steam pressure per square inch, and no more;

And we further certify that the said steamboat is permitted to run on the waters between *(here insert the places between which the steamboat is to be employed in running, and the seasons or period of time during which she may be so employed and for which the certificate is granted)* and that she is adapted and fit to carry *(here insert the number)* passengers and no more *(as the case may be)*.

Date *(of time and place.)*

A. B.,
Inspector of hulls and equipment.

C. D.,
Inspector of boilers and machinery.

SCHEDULE B.

Certificate for a freight boat under 150 tons gross, or a tugboat, fishing boat, or pleasure yacht, steam dredge, or elevator, or like vessel.

Having examined the boiler and machinery of the steamboat *(name or as the case may be)* of whereof is owner *(or are owners)* and is master, on this day of A. D. 18 .

The particulars of her gross and register tonnage, as shown on her certificate of registry, being as follows:

	TONS.
Tonnage under tonnage deck....................	
Houses on deck (*naming them*)....................	
Total gross tonnage....................	
Deduct for engine room....................	
Register tonnage....................	

(If not registered omit this statement of tonnage.)

I *(inspector's name)* inspector of boilers and machinery, do hereby certify that her engine, boiler and machinery, are sufficient for a freight boat under 150 tons *(or as the case may be)* and may be so used without hazard to life; that the engine of the said *(steamboat)* is of nominal horse-power and that the boiler of the said *(steamboat)* can carry with safety pounds *(here insert number of pounds)* per square inch of steam pressure, and no more: and that she is provided with one life buoy, having a proper heaving line attached and so placed as tc be ready for immediate use when required.

Date *(time and place)*.

C. D.,
Inspector of boilers and machinery.

SHEDULE C.

Certificate for a barge, boat, bateau or scow, to carry passengers in tow of a tug steamboat.

I (*inspector's name*) inspector of hulls and equipment, having examined the barge, boat, bateau or scow (*as the case may be*) of which is owner and is master (*or* the person in charge) on this A. D. 18 , do hereby certify that the said vessel is fit, safe and properly equipped in all respects to carry passengers in tow of a tugboat, on the waters (*here describe the locality on which she is to be employed*) and that she is provided with one life buoy having a proper heaving line attached, and so placed as to be ready for immediate use.

Date (*time and place.*)

A. B.,
Inspector of hulls and equipment.

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47 VICTORI ' -CHAP. 20.

AN ACT TO AMEND "THE STEAMBOAT INSPECTION ACT, 1882," BY REDUCING THE FEES PAYABLE ON RENEWAL OF ENGINEERS' LICENSES.

(Assented to 19th April, 1884.)

Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:

1. The fee payable on the renewal of an engineer's certificate, under section forty-five of "*The Steamboat Inspection Act, 1882,*" shall be one dollar, instead of five dollars, as mentioned in the said section, which is hereby amended accordingly.

48-49 VICTORIA—CHAP. 75.

AN ACT TO FURTHER AMEND "THE STEAMBOAT INSPECTION ACT, 1882."

(Assented to 20th July, 1885.)

In amendment of "*The Steamboat Inspection Act, 1882,*" Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:

1. Section forty-six of the said Act is amended by inserting after "third-class engineers," in the first sub-section, the words "fourth-class engineers;" and by adding the following as sub-section five of the said section:

"(5). A fourth-class engineer may act in the capacity of second engineer to a second-class engineer or third-class engineer, on any freight steamboat, or any other steamboat except a sea-going passenger steamboat of more than one hundred nominal horse-power, but shall not act as chief engineer on any steamboat requiring under this Act engineers holding certificates."

2. Section forty-eight of the said Act is amended by adding the following to the first sub-section as part thereof:

"No person shall be qualified for a fourth-class engineer's certificate who is not over twenty-one years of age, and who has not served an apprenticeship of not less than thirty-six months in a steam engine shop, and been employed on the making and repairing of steam engines; or, if he has not served such apprenticeship, he must prove that he has been employed for not less than thirty-six months as a journeyman mechanic in some workshop on the making and repairing of steam engines; or he must have served at least thirty-six months in the engine room of a steamboat as engineer on the watch; or he must have served not less than forty-eight months in the fire-hold of a steamboat of not less than thirty nominal horse-power, as fireman on the watch; and in any of the above mentioned cases twelve months of the time prescribed may have been served in a boiler shop on the making and repairing of steam boilers; he must be able to read, and must write a legible hand; he must understand the construction and operation of the feed water-pump, water-gauges and safety-valves; he must know when a boiler is foaming, and how to stop the foaming; also the danger from neglect to keep a boiler clean, and the usual methods of cleaning it."

3. The forty-fifth section of the said Act is amended by adding the following thereto as sub-section five thereof:

"(5.) Any person claiming to be qualified to perform the duties of a fourth-class engineer may apply for a certificate as such to the Chairman of the Board of Inspectors, who may examine or cause an inspector to examine him and the proofs he produces in support of his claim, and any such examination may be on oath, which any inspector may administer; and if the Chairman is satisfied that the character, habits of life, knowledge and experience in the duties of the position of the applicant, are such as authorize his granting the applicant a certificate, he may do so, and such certificate shall be renewable yearly; and for every such certificate the applicant shall pay the sum of five dollars, and for every renewal thereof one dollar; and the said sums shall be paid and applied in the manner provided in the first sub-section of this section; and the said certificate shall be subject to be revoked for the same causes and subject to the same conditions and consequences, as the license or certificate of an engineer of any other class under sub-section two of this section.

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49 VICTORIA—CHAP. 34.

AN ACT FURTHER TO AMEND "THE STEAMBOAT INSPECTION ACT, 1882."

(Assented to 2nd June, 1886.)

Whereas it appears by a despatch from Her Majesty's Secretary of State for the Colonies, and other documents laid before Parliament by His Excellency the Governor General, that the Board of Trade of the United Kingdom have reported to Her Majesty that they were satisfied that the examination under the Canadian laws of persons applying for certificates of competency as engineers on board sea-going steamboats or vessels propelled wholly or in part by steam, are so conducted as to be equally efficient with the examinations for the like purpose under the Imperial Acts relating to merchant shipping, and are granted on such principles as to show like qualifications and competency as those granted under the said Imperial Acts, and are liable to be forfeited for the same reasons and in the like manner; and that Her Majesty will be advised to extend the provisions of the Order in Council made under the "*Merchant Shipping (Colonial) Act, 1869*," and dated the twenty-ninth day of June, one thousand eight hundred and eighty-two, making the colonial certificates of competency granted by the Minister of Marine and Fisheries in Canada to persons intending to act as masters or mates on board British sea-going ships of the same force as if they had been granted under the said Imperial Acts, to certificates of competency as first-class or second-class engineers for sea-going British ships; and in view of such extension it is expedient to amend the said "*Steamboat Inspection Act, 1882*," as hereinafter mentioned: Therefore Her Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:

1. Certificates of competency granted under "*The Steamboat Inspection Act, 1882*," to persons examined and found qualified under it as engineers, shall hereafter be granted by the Minister of Marine and Fisheries, instead of the Board of Inspection, and shall be on parchment and signed by the said Minister instead of the Chairman of the said Board; and any such certificate in force at the time of the passing of this Act, may be delivered up by the holder thereof to the said Minister, who may thereupon give to the holder a certificate on parchment and signed as hereby required.

2. Every certificate of competency to which it is intended that the said order of Her Majesty in Council shall apply, shall have the word "*Canada*" inserted prominently on its face and back, and shall be as nearly as possible similar in shape and form to corresponding certificates of competency for the foreign trade granted by the Board of Trade under the Acts relating to merchant shipping, and shall be numbered in consecutive order:

(2). Such certificate shall be granted only on proof that the previous service at sea of the person applying for the same has been such as is required by the regulations for the time being in force in the United Kingdom with respect to certificates of like grade:

(3). Every such certificate of competency shall be subject to be suspended or cancelled by the Board of Trade for like offences or causes and in like manner, as certificates granted under the Imperial Acts relating to merchant shipping, all the provisions whereof or of any order of Her Majesty in Council made under them shall apply to such certificates—or to be revoked for cause by the Minister of Marine and Fisheries under the provisions of the Act hereby amended.

3. Certificates of competency as first or second-class engineers in sea-going ships, granted under the Imperial Acts relating to merchant shipping, shall, after the time of the coming into force of the order of Her Majesty in Council referred to in the preamble to this Act, and while in force under the said Imperial Acts, be of the same force and effect in Canada as if granted under the Act hereby amended, but subject to be forfeited for cause, as respects ships to which "*The Steamboat Inspection Act, 1882,*" applies, as if granted under the said Canadian Act.

4. The sections hereinafter referred to as amended are those of "*The Steamboat Inspection Act, 1882.*"

5. Section nine is so amended that is shall read and have effect as follows:

"9. The Chairman of the Board of Steamboat Inspection, who shall also be the supervising inspector, may at any time, inspect or examine the hull, equipment, boiler, and machinery of any steamboat, and if he suspects any inspector of having neglected his duty in relation to such steamboat, or in any other respect, he may call a meeting of the Board to investigate the case, or may himself investigate it; and the result of such investigation shall be forthwith communicated in writing to the Minister of Marine and Fisheries: he shall receive and examine all reports and accounts of inspectors, and report fully to the Minister upon all matters pertaining to his official duties, so as to ensure, as far as possible, a uniform and efficient administration of the inspection laws, rules and regulations."

6. The first sub-section or paragraph of section sixteen is so amended that it shall read and have effect as follows:

"16. If the inspector of hulls who inspects any steamboat in the manner required by this Act, approves the hull and equipment of such steamboat, he shall sign a certificate in triplicate according to the form A in the schedule to this Act, and such triplicate certificate shall be delivered by him to the inspector of boilers and machinery for the same district, who, when he has inspected and approved the boilers and machinery of the steamboat, shall make and sign in triplicate upon the same sheet of paper, a certificate according to the form A, in the said schedule, and shall deliver two of the triplicates of the said certificates to the owner or master of the steamboat, who shall deliver one triplicate to the chief officer of Customs as aforesaid, and shall cause the other to be posted up, framed and protected by glass, in some conspicuous part of the steamboat for the information of the public; and the inspector of boilers and machinery shall retain the other triplicate for the purposes of this Act."

7. Sub-section four of section sixteen is so amended that it shall read and have effect as follows:

"(4). Each inspector shall keep a register of the inspections and certificates made and granted by him, in such form and with such particulars respecting them, as the Chairman of the Inspection Board shall, from time to time, require, and shall furnish copies thereof to the Chairman when required."

8. Sub-section three of section seventeen is amended by inserting the words "their strength compared with" after the words "according to" in the eighth line thereof:

(2). Sub-section four of section seventeen is amended by inserting the words "their strength compared with" after the words "according to" in the seventeenth line thereof:

(3). The first paragraph of sub-section seven of section seventeen is so amended that it shall read and have effect as follows:

"(7). The external working pressure to be allowed on plane circular iron furnaces and flues subjected to such pressure, when the longitudinal joints are welded or made with a butt-strap, shall be determined by the following formula:"

9. Sub-section thirteen of section seventeen is so amended that it shall read and have effect as follows:

"(13). Donkey boilers on steamboats shall be provided with a safety valve which may be locked up."

10. Sub-section two of section nineteen is so amended that it shall read and have effect as follows:

"(2). The boiler cocks and valves attached to the boilers shall be substantially made, and in no case shall they be attached to the boilers by screwing into the plate, unless, as an additional security, bolted flanges be used in addition to such attachment."

11. Sub-section four of section nineteen is so amended that it shall read and have effect as follows:

"(4). The lock-up safety valves shall be of a construction approved by the Board of Steamboat Inspection—such valves to be tested and proved by an inspector before use; and no inspector shall grant a certificate to any steamboat unless the boiler, or each boiler if more than one, of such steamboat, be provided with a safety valve."

12. Sub-section two of section thirty-two is hereby repealed.

13. Each life-preserver required by section thirty-five shall have a buoyancy equal to sustaining twenty-three pounds of iron immersed in water.

14. The following provision is hereby added to the first sub-section or paragraph of section thirty-nine, after the words "in use on board:"—"and no coal oil lamp shall be used between decks on any passenger steamboat in which hay or other inflammable material is carried, under a penalty of one hundred dollars for each contravention of this provision, nor shall any coal oil which will not bear a test of three hundred degrees Fahrenheit without taking fire be used on any passenger steamboat."

15. So much of section forty-five as requires that the certificate of any engineer shall be subject to renewal, yearly or otherwise, is repealed, as is also so much of the said section as authorizes the Board of Inspection to grant any such certificate, and every certificate hereafter granted shall be for life or during good conduct, and shall be signed by the Minister of Marine and Fisheries; and for every such certificate granted on the delivery up under section one of this Act of an unexpired certificate, or on the expiration of the term for which any certificate was granted, the applicant shall pay one dollar, but the sum payable for the first certificate to an engineer of any class, or for a certificate raising him to a higher class after re-examination, shall be as now, five dollars; and the said sums shall be paid and applied as provided in the said section forty-five.

16. Sub-section four of section forty-six is hereby amended by adding after "as" in the first line the words "second or third-class engineers or as."

17. Section fifty-two is so amended that it shall read and have effect as follows:

"52. Each chief officer of Customs shall demand of the owner or master of every steamboat entered, cleared or otherwise officially dealt with by such officer, the production of the certificate of inspection of such steamboat and of the receipt for the payment of the rate or duty mentioned in section fifty of this Act, in respect of such steamboat; and if such certificate and receipt are not so produced, then such chief officer shall seize and detain the said steamboat until the same are produced and exhibited, and any penalty incurred and lawfully imposed on such steamboat under the provisions of this Act, has been paid in full; and in default of payment such chief officer shall sell such steamboat for the payment of such rate or duty and penalties, in the usual manner, and shall deal with the proceeds as if the penalties were incurred for violation of the Customs laws."

18. Section thirty-six is so amended that it shall read and have effect as follows:

"36. A cork jacket with shoulder straps and waist lines for fastening the same around the body, or such other description of life-preservers as the Governor in Council approves, shall be the form of life-preserver to be used on passenger steamboats."

19. Schedule A of the said Act is so amended that it shall read and have effect as follows:

SCHEDULE A.

"*Certificate of the Inspector of Hulls and Equipment, for a steamboat to carry passengers, or a freight boat of or over 150 tons gross.*

"Having examined the hull and equipment of the steamboat *(name)*, of , whereof is *(or* are) owner *(or* owners) and is master, on this day of , A. D., 18 .

"The particulars of her gross and register tonnage, as shown on her certificate of registry being as follows:

	TONS.
Tonnage under tonnage deck........................	
Houses on deck *(naming them)*......................	
Total gross tonnage....	
Deduct for engine room............................	
Register tonnage..........................	

"I *(inspector's name)*, inspector of hulls and equipment, do hereby certify that her hull is in all respects staunch, sea-worthy and in good condition for navigation; that the equipment of the vessel throughout is in conformity with the requirements of "*The Steamboat Inspection Act, 1882*," the said steamboat having on board, properly placed and in good order for immediate service—

"*(Number)* boats, having together a carrying capacity for persons; lifeboats, having (together) a carrying capacity for persons; life-preservers; wooden floats; fire buckets; axes; lanterns and one life buoy having a proper heaving line attached; and that she has the fire-pumps, hose and other appliances for extinguishing fire, required by the said Act, and placed as therein provided, and in every way efficient and according to the requirements of the said Act; and I further certify that the said steamboat is permitted to run on the waters between *(here insert the places between which the steamboat is to be employed in running, and the season or period of time during which she may be so employed, and for which the certificate is granted, and if she is a passenger steamboat, add:* and that she is adapted and fit to carry *(number)* passengers and no more *(as the case may be).*

"Date *(time and place).*

A. B.,
Inspector of Hulls and Equipment.

"*Certificate of the Inspector of Boilers and Machinery for the same Steamboat.*

"And I *(inspector's name),* inspector of boilers and machinery, do hereby certify that the engine, boiler and machinery of the steamboat *(name)* are sufficient and suitable to authorize her being lawfully employed in the carriage of passengers *(or* as a freight boat, *or* as a ferry boat, *as the case may be),* without hazard to life, on the route on which she is to be placed, as hereinafter mentioned; that the engine of the said steamboat is of   nominal horse-power, and that her boiler can carry with safety   pounds of steam pressure per square inch, and no more.

"*Add the certificate as to the waters on which the steamboat is to run, as in the certificate of the inspector of hulls and equipment.*

"Date *(time and place).*

C. D.,
Inspector of Boilers and Machinery.

20. Nothing in this Act shall invalidate or affect any inspection made or certificate of inspection granted in conformity to the Act hereby amended, before the passing of this Act.

RULES AND REGULATIONS

FOR THE CONDUCT OF STEAMBOAT INSPECTORS AND FOR THE INSPECTION OF STEAMBOATS.

BOILERS.

1. When cylindrical boliers or the cylindrical parts of boilers composed of iron plates are made of the best material with all the rivet holes drilled in place and all the seams fitted with double butt-straps, each of at least $\frac{5}{8}$ the thickness of the plates they cover, and all the seams at least double rivetted with rivets having an allowance of not more than seventy-five per cent over the single shear, and provided that the boilers have been open to inspection during the whole period of construction, then four may be used as the factor of safety. The tensile strength of the material is to be taken as equal to 48,000 pounds per square inch with the grain, and 42,000 pounds across the grain. When the above conditions are not complied with, the addition, in the following scale, must be added to the factor according to the circumstances of each case.

A	.15	To be added when all the holes are fair and good in the longitudinal seams, but drilled out of place after bending.
B	.3	To be added when all the holes are fair and good in the longitudinal seams, but drilled out of place before bending.
C	.3	To be added when all the holes are fair and good in the longitudinal seams but punched after bending instead of being drilled.
D	.5	To be added when all the holes are fair and good in the longitudinal seams, but punched before bending.
E*	.75	To be added when all the holes are not fair and good in the longitudinal seams.

F	.1	To be added if the holes are all fair and good in the circumferential seams, but drilled out of place after bending.
G	.15	To be added if the holes are fair and good in the circumferential seams, but drilled before bending.
H	.15	To be added if the holes are fair and good in the circumferential seams, but punched after bending.
I	.2	To be added if the holes are fair and good in the circumferential seams, but punched before bending.
J*	.2	To be added if the holes are not fair and good in the circumferential seams.
K	.2	To be added if double butt-straps are not fitted to the longitudinal seams, and the said seams are lap and double rivetted.
L	.1	To be added if double butt-straps are not fitted to the longitudinal seams, and the said seams are lap and treble rivetted.
M	.3	To be added if only single butt-straps are fitted to the longitudinal seams and the said seams are double rivetted.
N	.15	To be added if only single butt-straps are fitted to the longitudinal seams, and the said seams are treble rivetted.
O	1.	To be added when any description of joint in the longitudinal seams is single rivetted.
P‡	.1	To be added if the circumferential seams are fitted with single butt-straps and are double rivetted.
Q‡	.2	To be added if the circumferential seams are fitted with single butt-straps and are single rivetted.
R‡	.1	To be added if the circumferential seams are fitted with double butt-straps and are single rivetted.
S‡	.1	To be added if the circumferential seams are lap joints and are double rivetted.
T	.2	To be added if the circumferential seams are lap joints and are single rivetted.
U	.25	To be added when the circumferential seams are lap, and the strakes of plates are not entirely under or over.

V	.3	To be added when the boiler is of such a length as to fire from both ends, or is of unusual length, such as flue boilers; and the circumferential seams are fitted as described opposite P, R and S, but of course when the circumferential seams are as described opposite Q and T, V .3 will become V .4.
W*	.4	To be added if the seams are not properly crossed.
X*	.4	To be added when the iron is in any way doubtful, and the inspector is not satisfied that it is of the best quality.
Y†	1.	To be added if the boiler is not open to inspection during the whole period of its construction.

The strength of the joints is found by the following method:—

$$\frac{(\text{Pitch}-\text{Diameter of rivets})\times 100}{\text{Pitch}}$$ = percentage of strength of plate at joint as compared with the solid plate.

$$\frac{(\text{Area of rivets}\times\text{No. of rows of rivets})\times 100}{\text{Pitch by thickness of plate}}$$ = percentage of strength of rivets as compared with the solid plate.††

Where marked * the allowance may be increased still further if the workmanship or material is very doubtful or unsatisfactory.

†† If the rivets are exposed to double shear multiply the percentage as found by 1.75.

† When surveying boilers that have not been open to inspection during construction the case should be submitted to the Chairman as to the factors to be used.

P‡ .1, Q‡ .2, R‡ .1, S‡ .1, shall not apply to the end or circumferential seams, if such seams are sufficiently stayed by through bolts; nor to the seams between the square and round part of shell, in cylindrical boilers with square furnaces, when such seams are double rivetted.

Then take iron as equal in tensile strength to 48,000 pounds per square inch and use the smallest of the two percentages as the strength of the joint, and adopt the factor of safety as found from the preceding scale:

$$\frac{(48{,}000 \times \text{percentage of strength of joint}) \times \text{twice the thickness of the plate in inches}}{\text{Inside diameter of boiler in inches} \times \text{factor of safety}}$$

= pressure to be allowed per square inch on the safety valves.

For steel plates of the best quality the tensile strength may be taken as equal to 60,000 pounds per square inch, using the same factor of safety.

Plates that are drilled in place must be taken apart and the burr taken off and the holes slightly countersunk from the outside.

Butt-straps must be cut from plates and not from bars, and must be of as good quality as the shell plates, and for the longitudinal seams must be cut across the fibre.

The rivet holes may be punched or drilled when the plates are punched or drilled out of place, but when drilled in place must be taken apart and the burr taken off and slightly countersunk from the outside.

When single butt-straps are used and the rivet holes in them punched they must be one eighth thicker than the plates they cover.

The diameter of rivets must not be less than the thickness of the plates of which the shell is made, but it will be found when the plates are thin, or when lap joints or single butt-straps are adopted that the diameter of the rivets should be in excess of the thickness of the plates.

The distance of the rivet holes from the ends or edge of the plates shall not be less than the diameter of the rivet.

Dished ends that are not truly hemispherical must be stayed; if they are not theoretically equal in strength to the pressure needed they must be stayed as flat surfaces, but if they are theoretically equal in strength to the pressure needed the stays may have a strain of 10,000 pounds per effective square inch of sectional area.

Inspectors will remember that the strength of a sphere to resist internal pressure is double that of a cylinder of the same diameter and thickness.

2. The neutral parts of boiler shells under steam domes must be sufficiently stiffened and stayed.

The sides of boilers having square furnaces and half round tops must be stayed from side to side of the shell, over the furnace, one or more rows of these stays to be placed well above the centre of the cylindrical part.

Screw stays are not to be used when supporting flat surfaces at any angle but a right angle to the surface supported, their diameter to be measured inside the thread.

The longitudinal seams in the cylindrical shell of boilers should be as far as possible from the bottom.

The inside diameter of the outside strake or course in the cylindrical shell of a boiler is to be taken as the measure of its diameter.

3. In cylindrical superheaters the strength of the joints and the factor of safety is found in a similar manner as for cylindrical boilers and steam receivers, but instead of using 48,000 pounds as the tensile strength of iron, 24,000 pounds is adopted, unless where the heat or flame impinges at or nearly at right angles to the plate, then 18,000 pounds is substituted.

In all cases the internal steam pipes should be so fitted that the steam in flowing to them will pass over all the plates exposed to the impact of heat or flame.

Superheaters or water jackets should, as regards inspection, be deemed to be the most important part of the boilers and must be inspected inside and outside; those that cannot be entered (on account of their size) must have a sufficient number of doors through which a thorough inspection of the whole of the interior can be made.

Special attention should be paid to the inspection of superheaters, as with high pressure the plates may become dangerously weak and not give any sound to indicate their state when tested with the hammer; the plate should therefore be occasionally drilled. Drain pipes must be in all cases fitted to superheaters in which a collection of water in the bottom is possible.

Superheaters that can be shut off from the main boilers must be fitted with a Government lock-up safety valve of sufficient size, but the least size passed shall not be less than three inches diameter.

4. The areas of diagonal stays are found in the following way:

Find the area of a direct stay needed to support the surface, multiply this area by the length of the diagonal stay and divide the product by the length of a line drawn at right angles to the surface supported to the end of the diagonal stay, the quotient will be the area of the diagonal stay required.

5. When the tops of combustion boxes or other parts of a boiler are supported by solid rectangular girders, the following formula, which is used by the Board of Trade, will be useful for finding the working pressure to be allowed on the girders, assuming that they are not subjected to a greater temperature than the ordinary heat of steam, and are further sustained by hanging stays, as provided by sub-section twelve of section seventeen of the Act, and in case of combustion chambers, that the ends are fitted to the edges of the tube plate and the back plate of the combustion box:

$$\frac{C \times d^2 \times T}{(W-P)\, D \times L} = \text{Working pressure.}$$

W=Width of combustion box in inches.

P=Pitch of supporting bolts in inches.

D=Distance between the girders from centre to centre in inches.

L=Length of girder in feet.

d=Depth of girder in inches.

T=Thickness of girder in inches.

C=Five hundred when the girder is fitted with one supporting bolt.

C=Seven hundred and fifty when the girder is fitted with two or three supporting bolts.

C=Eignt hundred and fifty when the girder is fitted with four supporting bolts.

The working pressure for the supporting bolts and for the plate between them, shall be determined by the rule for ordinary stays.

6. The flat end of all boilers, as far as the steam space extends, and the ends of superheaters should be fitted with shield, or baffle plates, where exposed to the hot gases of the uptake, as all the plates subjected to the direct impact of heat or flame are liable to get injured unless covered with water.

7. Donkey boilers that are in any way attached to, or connected with the main boilers, or with the machinery used for propelling the ship, must be inspected and fitted the same way as the main boilers, and have a water and steam gauge, and all other fittings complete, and as regards safety valves must comply with the same regulations as the main boilers,

and no safety valve shall be passed less than two inches diameter.

8. No boiler or steam chamber is to be so constructed, fitted or arranged as that the escape of steam from it through the safety valve can be wholly or partially intercepted by the action of any other valve.

A stop valve must always be fitted between the boiler and the steam pipe, and when two or more boilers are connected with a steam receiver or superheater, between each boiler and superheater or steam receiver. The object of this is obvious, viz.: to avoid the failure of all the boilers through the failure of one. The necks of stop valves should be as short as practicable.

9. Each boiler must be fitted with glass water gauge, at least two test cocks, and steam gauge, that is to say, each boiler must be fitted with all the fittings as complete as if there were only one boiler.

Boilers that fire at both ends, and those of unusual width, must have water gauges and test cocks at each end or side, as the case may be. When a steamer has more than one boiler, and those boilers are fitted with stop valves, each boiler must be treated as a separate one, and have all the requisite fittings.

10. Inspectors are to be most careful not to give any official sanction to any new arrangement or construction of marine steam boilers, without first obtaining the permission of the Chairman in writing, nor are they allowed to give any written approval of any invention or arrangement unless by direction of the Board, and whenever they know that any invention or new arrangement is to be fitted to a vessel that is intended to have a passenger certificate, they should as soon as possible obtain plans and submit the same to the Chairman.

11. When the longitudinal seams in cylindrical furnaces are not welded or made with a butt-strap as provided in sub-section seven, section seventeen of the Act, the following constants will be substituted for 90,000.

Furnaces with butt joints and drilled rivet holes.	90,000 where the longitudinal seams are double rivetted and fitted with single butt-straps; 80,000 where the longitudinal seams are single rivetted and fitted with single butt-straps; 90,000 where the longitudinal seams are single rivetted and fitted with double butt-straps.

Furnaces with butt joints and punched rivet holes.	85,000 where the longitudinal seams are double rivetted and fitted with single butt-straps; 75,000 where the longitudinal seams are single rivetted and fitted with single butt-straps; 85,000 where the longitudinal seams are single rivetted and fitted with double butt-straps.
Furnaces with lap joints and drilled rivet holes.	80,000 where the longitudinal seams are double rivetted and bevelled; 75,000 where the longitudinal seams are double rivetted and not bevelled; 70,000 where the longitudinal seams are single rivetted and bevelled; 65,000 where the longitudinal seams are single rivetted and not bevelled.
Furnaces with lapped joints and punched rivet holes.	75,000 where the longitudinal seams are double rivetted and bevelled: 70,000 where the longitudinal seams are double rivetted and not bevelled; 65,000 where the longitudinal seams are single rivetted and bevelled; 60,000 where the longitudinal seams are single rivetted and not bevelled.

STEEL FURNACES AND FLUES.

12. The external working pressure to be allowed on plane circular steel furnaces and flues when subjected to such pressure, when the longitudinal joints are welded or made with a butt-strap, shall be determined by the following formula:

The product of 90,000 multiplied by the square of the thickness of the plate in inches, divided by the length of the flue, or furnace, in feet, plus one multiplied by the diameter in inches, will be the allowable working pressure per square inch in pounds; provided it does not exceed that found by the following formula:

The product of 10,000 multiplied by the thickness of the plate in inches, divided by the diameter (outside) of the flue or furnace, in inches, will be the allowable working pressure per square inch in pounds.

CORRUGATED STEEL FURNACES AND FLUES.

13. Steel flue furnaces when new, corrugated, and machine made, and practically true circles, the working pressure is found by the following formula, provided that the plane parts at the ends do not exceed six inches in length, and the plates are not less than $\frac{5}{16}$ inch thick.

$$\frac{12{,}500 \times \text{thickness in inches}}{\text{Mean diameter in inches}} = \text{Working pressure per sq. inch.}$$

When the furnaces are rivetted in two or more lengths the case should be submitted to the Chairman for consideration, as it may be necessary to make a reduction.

CORRUGATED IRON FURNACES.

14. The working pressure for corrugated iron furnaces practically circular, and machine made, provided the plane parts at the ends do not exceed six inches in length and the plates are not less than $\frac{5}{16}$ inch thick, should not be greater than that found by the following formula:

$$\frac{10{,}000 \times \text{thickness in inches}}{\text{Mean diameter in inches}} = \text{Working pressure per sq. inch.}$$

INSPECTION OF BOILERS.

15. Inspectors are to fix the working pressure of boilers by a series of calculations of the strength of the various parts, and according to the workmanship and material.

16. Before testing a boiler the inspector should examine it, take the necessary measurements and calculate what the working pressure should be, in accordance with the provisions of the Steamboat Inspection Act. If the test is not satisfactory the defects must be made good and the boiler re-tested. This instruction applies to superheaters, steam chests and water jackets as well as boilers.

17. If the boiler is too hot for the inspector to examine it efficiently with safety and convenience, he should decline to examine it and absolutely refuse to grant a certificate until he can make an efficient examination.

18. Inspectors should see all new boilers, and boilers that

have been taken out of a ship for a thorough repair, tested by hydraulic pressure up to at least one and one-half the working pressure that will be allowed previous to the boilers being placed in the vessel to test the workmanship, etc., but the working pressure is to be determined by the stay power, thickness of plates and strength of rivetting, etc., and not by the hydraulic test.

The hydraulic test should in no case exceed that provided by section seventeen of the Act, and it is never to be applied until the boiler has been opened up for examination and until the strength has been calculated from the necessary measurements taken from the boiler itself.

19. When a boiler is partially inspected by one inspector and the inspection is completed and the certificate granted by another, if the inspector who witnesses the test of the boilers by the hydraulic pressure has an opportunity of examining them inside and outside after the test, such inspector shall determine the pressure to be allowed on the boilers in question, taking care to inform the owners, makers or agents, and the inspector who is ultimately to grant a certificate, what pressure should in his opinion be allowed on them.

20. Cast iron must not be used for stays, and inspectors should also discourage the use of cast iron for chocks and saddles for boilers. Particular attention should be paid to chocking and fastening boilers to the vessel.

21. A pressure once allowed on a boiler of a passenger steamer is not, under any circumstances whatever, to be increased, unless the inspector has previously written for and obtained the sanction of the Chairman. In cases where an inspector is of opinion that an increased pressure may with safety be allowed, he should communicate with the inspector who last inspected the boiler, and if on learning the reason why the existing pressure was formerly allowed, the inspector is still of opinion that it may be increased, he should communicate all the facts of the case to the Chairman, but as above stated the pressure should not in any case be increased until the question has been decided by the Chairman.

22. In fixing the maximum working pressure on steamboat boilers, inspectors are to assume one hundred and twenty-five pounds to the square inch as the limit allowable for a new steel boiler forty-two inches in diameter, made in the best manner, of the best quality of steel plates, at least one quarter of an inch thick, with all the rivet holes drilled in place, the plates being then taken apart and the burrs removed, the

longitudinal seams in the shell being fitted with double butt steel straps cut across the grain of the plate and each of at least five-eighths the thickness of the plates they cover, and all the seams being at least double rivetted and having at least seventy per cent. of the strength of the solid plate, and all the flat surfaces stayed in the best manner and all the seams double rivetted, and they shall rate the working pressure of all steel boilers so made, whether of greater or less diameter, according to their strength compared with this standard, and in all such cases the test applied shall exceed the working pressure allowed for such boilers in the ratio of one hundred and ninety pounds to one hundred and twenty-five pounds, using the water in such tests at a temperature not exceeding sixty degrees Fahrenheit, and all percentages added to the factor of safety for inferior workmanship or material, are to be deducted from that pressure.

In fixing the maximum working pressure on steamboat boilers, inspectors are to assume one hundred pounds to the square inch, as the limit allowable for a new boiler forty-two inches in diameter, made of the best refined iron, at least one quarter of an inch thick, in the best manner and of the quality herein required, and shall rate the working pressure of all iron boilers, whether of greater or less diameter, according to their strength compared with this standard, and in all such cases the test applied shall exceed the working pressure allowed, in the ratio of one hundred and fifty pounds to one hundred, using the water in such tests at a temperature not exceeding sixty degrees Fahrenheit, and all percentages added to the factor of safety, for inferior workmanship or material, are to be deducted from that pressure.

23. In the case of zigzag rivetting the strength through the plate diagonally between the rivets is equal to that horizontally between the rivets, when diagonal pitch equals $\frac{6}{10}$ horizontal pitch plus diameter of rivet.

SAFETY VALVES.

24. Section nineteen of the Act provides that the boiler of every steamboat shall be fitted with one or more locked-up safety valves. Subsequent section further provides that the area of any locked safety valve or the joint areas of any locked safety valve to any boiler made or placed on board after the passing of this Act, shall not be less than half a square inch for each square foot of grate surface in or under the boiler.

In all cases the safety valves should be upon the boiler or as near as possible to it.

(1). Inspectors are instructed that in all new boilers and whenever alterations can be easily made, the valve chest should be placed directly on the boiler, and the neck or part between the chest and the flange which bolts on to the boiler should be as short as possible and be cast in one with the chest.

In any case in which an inspector is of opinion that it is positively dangerous to have a length of pipe between the boilers and the safety valve chest, it is his duty at once to insist on the requisite alterations being made before granting a certificate.

(2). Inspectors are to fix the limit of the weight to be placed on the safety valves and are to satisfy themselves that the boilers are in their judgment sufficient with the weight so placed.

In new vessels no safety valves should be passed less than two and one-half inches in diameter, and for donkey boilers and boilers having less than ten square feet of grate surface, not less than two inches in diameter.

(3). Care should be taken that the safety valves have a lift equal to at least one-fourth their diameter, that the area of the inlet and outlet openings for the passage of steam be not less than the area of the valve; where lever valves are used the distance between the centre of the valve and the centre of the fulcrum should not be less than the diameter of the valve.

(4). The size of the steel of which the spring is made in spring safety valves is found from the following formula taken from the Board of Trade Rules:

$$\sqrt[3]{\frac{S \times D}{c}} = d$$

S=The load on the spring in pounds.

D=The diameter of the spring (from centre to centre of wire) in inches.

d=The diameter of side of square of the wire in inches.

c=8,000 for round steel.

c=1,0000 for square steel.

The spring should be protected from the steam and impurities issuing from the boiler, and in case of the spring breaking means provided to keep it in position on the valve.

(5). A standard spring, if made of the best square cast steel, contains .25 of a square inch, the inside diameter is two inches, and the outside diameter three inches, it has thirteen complete coils with the ends and is eleven and one-half inches long. The working load is assumed at 600 pounds, one-sixth of its breaking load when hardened to a temper, just sufficient to break it, at which load it should deflect just one inch.

To find the sectional area for any other spring the pressure on the valve being given:

600 :: 700 : .25 : .29 sectional area of spring at 700 pounds load.

Suppose the pressure on the valve be 1,344 pounds then 600 : 1,344 :: .25 : .56 equal to a $\frac{3}{4}$ inch square bar; the other dimensions of the spring would be in like proportion.

(6). The following conditions should apply to all safety valves:

(*a*) Under no consideration whatever should the pressure rise in the boiler above the load placed on the safety valve.

(*b*) The relieving power of the safety valve or safety valves should be twice the generating power of the boiler under full fires.

(*c*) No disk or "pot safety valve" liable to open the full area of the valve suddenly, should be passed over four inches in diameter. When a larger area of safety valve is required, two or more valves may be used; but in all cases lifting gear must be provided for raising them singly or together.

(7). Safety valves must be placed in convenient and accessible places, that their adjustment and examination may be readily and efficiently made.

25.—DUTIES AND LIABILITIES OF ENGINEERS.

RULE I.—Engineers are required in all cases upon stopping of the engine to open the safety valves, so as to keep the steam in the boiler below the limit allowed by the inspector's certificate as prescribed by law, to open the doors or close the dampers, and when from accident or other cause, the water in the boiler has fallen below the point of safety, to put out the fires immediately.

RULE II.—Engineers shall keep the fire pumps and hose and their connections in perfect condition, ready for immediate use, and when found unfit for use from age or other cause, shall report their condition to the inspector of hulls by whom the steamer was last inspected.

RULE III.—Engineers when laying up a steamer in the fall, or when finally leaving her, are required to report to the owner and also to the inspector of the nearest district any defects of, or injury to, the boilers and machinery by which the safety of the same may be endangered. They shall also report to the inspector of the district at which the steamer next arrives, any accident happening to the boilers or machinery during the trip, and in case of omission to make such report, the license of the engineer so omitting shall be revoked.

RULE IV.—The chief engineer of a steamer is held accountable by the Board for the proper care and management of the boilers and machinery under his charge. He is, therefore, in no case to absent himself from the vessel while on her regular trips, unless a competent substitute be provided to fill his place during his absence.

RULE V.—Engineers on first taking charge of a steamer, and at least once a year thereafter, shall satisfy themselves by close examination that the braces, stays and pins of the boiler are in good order, and sufficient for the strain to which they may be subjected; they shall also satisfy themselves that the safety valves are in good working order and sufficient for the requirements of Rule 1, hereof.

RULE VI.—Engineers are to exhibit their certificates in the engine room along with a copy of these rules when required to do so.

RULE VII.—Management of boilers:

1. Getting up steam—Warm the boiler gradually. Steam should not be raised from cold water in less than four hours. If practicable, light the fires over night. By getting up steam too quickly, the boiler will soon be destroyed.

2. Firing—Fire regularly. Keep the sides up, and use the slice gently and as seldom as possible.

3. Feed water—Let the feed be regular and constant.

4. Glass gauge and try cocks—Keep the glass free and try the gauge cocks every fifteen minutes.

5. Safety valves—Lift each safety valve at least once a day, and always before getting up steam.

6. Low water—Put out the fires by drawing them or throwing ashes on them. Never use water. Low water should never occur.

7. Blowing off the boiler—Do not blow off by steam.

pressure; let the water run off if possible. See that the fires are all out.

8. Boiler purges—Never use any compositions to keep down incrustation, or oil or other impurities to remove it without the approval of the Chairman.

9. General rules—Keep the boiler clean inside and outside and free from leak. Never throw water in the furnace. Under high pressure, raise the safety valve gently. Lower the fires, or, if necessary, stop the engine when foaming to find the water level.

BRITISH BOARD OF TRADE RULES.

AN ABRIDGED EXTRACT FROM THE "BRITISH BOARD OF TRADE RULES."

In Great Britain, stationary boilers are built under the inspection of boiler insurance companies, while in this country and the United States, this is the exception instead of the rule. Locomotives boilers are designed by the superintendent of machinery in the old country and by the manufacturers in the new. Marine boilers are subjected to the control of the Board of Trade in Great Britain if for passenger, but usually are passed if, according to Lloyds' inspection, only for freight carriers.

The following may be taken as the rule, in substance, of the Board of Trade for to determine the strength of shell of boiler: When cylindrical boilers are made of the best material, with all rivet holes drilled in place and all the seams filled with double butt-straps, each of at least $\frac{5}{8}$ the thickness of the plates they cover, and all the seams at least double rivetted with rivets having an allowance of not more than seventy-five per cent. over single shear, and provided that the boilers have been open for inspection during the whole period of construction, then five for iron and four for steel may be used as factors of safety. The tensile strength of iron is to be taken as equal to 47,000 pounds per square inch with the grain, and 40,000 pounds across the grain. The boiler must be tested by hydraulic pressure to twice the working pressure, in the presence and to the complete satisfaction of the Board, steam engine and boiler surveyor. But when the above conditions are not complied with, the additions in the following scale must be added to the factor five, according to circumstances of each case:

SCALE OF ADDITIONS TO BE ADDED WHEN THE BOILER IS NOT MADE IN BEST MANNER.

(British Board of Trade.)

Reference Letters.	Amount to add.	Reasons for such Increase in Factor.
A	0.15	When all the holes are fair and in the longitudinal seams, but drilled out of place after bending.
B	0.3	When all the holes are fair and good in the longitudinal seams, but drilled out of place before bending.
C	0.3	When all the holes are fair and good, but are punched and not drilled after bending.
D	0.5	When all the holes are fair and good, but are punched and not drilled before bending.
E	0.75	When the holes in the longitudinal seams are not fair and good.
F	0.1	If the holes in the circumferential seams are fair and good, but drilled out of place after bending.
G	0.15	If the holes in the circumferential seams are fair and good, but drilled out of place before bending.
H	0.15	If the holes in the circumferential seams are fair and good, but are punched and not drilled after bending.
I	0.2	If the holes in the circumferential seams are fair and good, but punched and not drilled before bending.
J	0.2	If the holes in the circumferential seams are not fair and good.
K	0.2	If the longitudinal seams are double riveted lap joints and not double covered butts.

EXAMINATION OF ENGINEERS FOR CERTIFICATES OF COMPETENCY.

(Under the "Merchants Shipping Acts, etc.," amended 1862.)

1. Under the provisions of the "Merchants Shipping Acts, 1862," no "foreign-going steamship, or home trade passenger steamship, can obtain a clearence or transire, or legally proceed to sea from any port in the United Kingdom, unless in the case of a foreign-going steamship of one hundred horse-power or upwards, the first and second engineers, and in the case of a foreign-going steamship of less than one hundred nominal horse-power, or a home trade passenger steamship, the first or only engineer (as the case may be) have obtained and possess valid certificates, either of competency or service appropriate to their several stations in such steamship, or of a higher grade.

2. Every person who, having been engaged to serve as first or second engineer in a foreign-going steamship of one hundred nominal horse-power and upwards, or as first or only engineer in a foreign-going steamship of less than one hundred nominal horse-power, or in a home trade passenger steamship, goes to sea as such, first, second, or only engineer, without being at the time entitled to and possessed of such a certificate as the act requires, or who employs any person as first or second engineer in a foreign-going steamship of one hundred nominal horse-power and upwards, or as first or only engineer in a foreign-going steamship of less than one hundred nominal horse-power, or a home trade passenger steamship, without ascertaining that he is at the time entitled to and possessed of such certificate, for each offence incurs a penalty not exceeding fifty pounds.

3. The certificates of enginners are of two descriptions, viz.: certificates of competency and certificates of service; and for each description of certificates there are two grades, viz.: "first-class engineers certificate," and "second-class engineers certificates."

4. Certificates of competency will be granted to those persons who pass the requisite examinations and otherwise comply with the requisite conditions. For this purpose examiners have been appointed by the Board of Trade, and arrangements have been made for holding the examination in the places and at the time named in the table marked A. The examiners are selected generally from the engineer surveyors of the port, but no engineer surveyor is to undertake

the duty unless he receives special instructions from the Board of Trade.

5. The application for examination is to be made on form Exn. 3. The same rules are to be observed by engineers in making application to be examined, in paying the fees, and in forwarding testimonials, as in the case of application by masters and mates.

QUALIFICATIONS FOR CERTIFICATES OF COMPETENCY.

6. Second-class Engineer. A candidate for a second-class engineer's certificate must be twenty-one years of age;

(a) He must have served an apprenticeship to an engineer, and prove that during the period of his apprenticeship he has been employed on the making and repairing of engines: or if he has not served an apprenticeship, he must prove that for not less than three years he has been employed in some factory or workshop, on the making or repairing of engines. In either case he must also have served one year at sea in the engine room; or

(b) He must have served at least four years at sea in the engine room.

(c) He must be able to give a description of boilers, and the method of staying them, together with the use and management of the different valves, cocks, pipes, and connections.

(d) He must understand how to correct defects from accident, decay, etc., and the means of repairing such defects.

(e) He must understand the use of the barometer, thermometer, hydrometer, and salenometer.

(f) He must state the cause, effects, and usual remedies for incrustation and corrosion.

(g) He must be able to state how a temporary or permanent repair could be effected in case of derangement of a part of machinery, or total break-down.

(h) He must write a legible hand and understand the first five rules of arithmetic, and decimals.

(i) He must be able to pass a creditable examination as to the various constructions of paddle and screw engines in general use; as to the details of the different working parts, external and internal, with the use of each part.

7. First-class Engineer. A candidate for a first-class engineer's certificate, must be twenty-two years of age. In

addition to the qualification required for a second-class engineer,

(*a*) He must either possess, or be entitled to a first-class engineer's certificate of service; or in the event of his not being so possessed or entitled, he must have served for one year with a second-class engineer's certificate of competency. By this it is intended that the same rule shall be observed in the examination of engineers who are not in possession of a first-class certificate of service, as is obtained in the examination of masters and mates, viz.: that before the certificate of a higher grade is granted, certain service in the lower grade must be performed. The examiners should therefore be satisfied that applicants for the first-class engineer's certificate have not only been in possession of a second-class certificate for twelve months, but that they have actually served for a period of not less than twelve months in the engine room, with a second-class certificate, in the capacity of a second engineer; and that their names have been entered in the articles of agreement accordingly.

(*b*) He must be able to make rough work drawings of the different parts of the engines and boilers.

(*c*) He must also be able to take off and calculate indicator diagrams.

(*d*) He must be able to calculate safety valves, pressure, and the strength of the boiler.

(*e*) He must be able to state the general proportions borne by the principal parts of the machinery to each other.

(*f*) He must be able to explain the method of testing and altering the setting of the slide valves, and of testing the fariness of the paddle and screw shafts and of adjusting them.

(*g*) He must be conversant with surface condensation, superheating, and the working of steam expansively.

(*h*) His knowledge of arithmetic must include the mensuration of superficies and solids, and the extraction of the square root.

8. An extra first-class engineer's examination is voluntary, and is intended for such persons as wish to prove their superior qualifications, and are desirous of having certificates for the higher grade granted by the Board of Trade. The candidate must be entitled to or possessed of a first-class engineer's certificate of competency, and in addition to the qualifications required for a first class-engineer,

(*a*) He must possess a thorough knowledge of the construction and working of marine engines and boilers in all their parts, and be so far acquainted with the elements of theoretical machines as to comprehend the general principles on which the machine works.

(*b*) He must understand how to apply the indicator and draw the proper conclusions from the diagrams.

(*c*) He must be acquainted with the principles of expansion, and able to prove, or at least to illustrate, the use of the expansion gear.

(*d*) He must be able to draw rough sketches of any part of the machinery, with figured dimensions fit to work from.

GENERAL RULES AS TO EXAMINATIONS AND FEES.

9. The examination will be partly *viva voce*, and partly by examination papers. It will be directed specially to the above points, and to the duties and business of an engineer generally.

If the candidate passes the *viva voce* examination creditable, a set of questions will be given to work out. He will be allowed to work out these questions according to the method he is accustomed to use, and will be allowed five hours to perform the work; and

(*a*) If at the expiration of the time allowed he has worked out correctly the whole of the questions set him, he will be declared to have passed.

(*b*) If at the expiration of the time allowed he has not worked out the whole of the questions set him, but if the result of the *viva voce* examination taken in connection with the answers to such of the questions as he has worked out are sufficient to satisfy the examiner that the applicant is competent to take charge of engines of one hundred nominal horse-power or upwards, he will be declared to have passed.

(*c*) In other cases he will be declared to have failed. A report of the examination, and the examination papers, will be forwarded to the Board of Trade on the form (Exn. 15).

10. The fee for examination must be paid to the superintendent of the mercantile marine office. If a candidate fail in his examination, half the fee he has paid will be returned to him by the superintendent on his producing the form Exn. 17, which will be given him by the examiner.

The fees are as follows: First-class engineer's certificate, whether extra or ordinary, £2. Second-class engineer's certificate, £1. For first-class engineer's certificate, if already in possession of a second-class certificate, £1.

11. If the applicant passes he will receive a form, Exn.

16, from the examiner, which will entitle him to receive his certificate of competency from the superintendent of the mercantile marine office of the port to which he has directed it to be forwarded. If his testimonials have been sent to the registrar-general of seamen to be verified, they will be returned with the certificate.

12. If an applicant is examined for the higher grade and fails, but passes an examination of the lower grade, he may receive a certificate accordingly, but no part of the fee will be returned.

13. If the applicant fails in working out the examination papers, he may present himself for re-examination whenever he thinks he has acquired sufficient knowledge to enable him to pass. But if he fails in the *viva voce* or practical part of the examination, he may not present himself for re-examination until the expiration of three months from the date of failure.

CERTIFICATES OF SERVICE.

14. Every person who, before the 1st April, 1862, had served as either first engineer in a British foreign-going steamship of one hundred nominal horse-power and upwards, or who has attained or attains the rank of engineer in the service of Her Majesty, or of the East India Company, is entitled to a first-class engineer's certificate of service; and every person who, before the above mentioned date, has served as second engineer in any British foreign-going steamship of one-hundred nominal horse-power or upwards, or as first or only engineer in any other steamship, or who has attained or attains the rank of first-class assistant engineer in the service of Her Majesty, is entitled to a second-class engineer's certificate of service.

15. Application for certificates of service must be made on the printed form Exn. 22, to be obtained free of charge of the registrar-general of seamen, Adelaide Place, London Bridge, London, or of the superintendent of any mercantile marine office.

LIST OF EXAMINATION DAYS AT FOLLOWING PLACES.

BRISTOL.—Second and fourth Tuesday in each month.

DUNDEE.—Thursday in each week.

GLASGOW AND GREENOCK.—Thursday, held alternately of each place.

HULL.—First and third Tuesday in each month.

LIVERPOOL.—Thursday in each week.

LONDON.—Wednesday in each week.

SHIELDS, NORTH.—First and third Wednesday in each month.

SOUTHAMPTON.—First and third Tuesday in each month.

SUNDERLAND.—The last Monday in each month.

NOTICE OF ALTERATION IN EXAMINATION PAPERS.

From the first day of February, 1874, all candidates presenting themselves for examination will be required to give written answers to eight out of a list of ten questions selected from form Exn. 15 A. "Elementary questions for the first examinations of engineers for certificates of competency, and of masters and mates for certificates in steam." These questions are intended to furnish a record, to some extent, of the candidate's knowledge at the time of his examination, and also to induce the candidate to pay more attention to his handwriting and spelling.

The form Exn. 15 B, on which these answers will be written, contains also some questions as to the experience of the candidate, to be answered by him in writing. A copy of Exn. 15 B, is contained in form Exn. 15 A.

The *viva voce* questions on the practical management of steam engines and boilers will remain on the same footing as at present. Examiners may add to their *viva voce* questions any of those contained in Exn. 15 A.

The arithmetical questions on forms Exn. 10 and Exn. 11 will be cancelled, and forms Exn. 10 A. and Exn. 11 A, or other similar forms to be from time to time issued, will be used instead. No further notice will be given of the changing of these forms. The questions will be promiscuous exercises on the arithmetic of marine engineering, and the candidate will not be expected to work all the questions, but only so many of them as he may think sufficient to satisfy the examiner that he possesses the required knowledge of arithmetic, and that he can apply it. The arithmetical standard for candidates is not altered; it will continue as at present to include decimal fractions for second-class, and to include square root for first-class candidates.

First-class candidates will be required to make, from a copy, an intelligible hand sketch, or a working or drawing of some one or more of the principal parts of a steam engine, and to mark in, without copy, all the necessary dimensions in figures, so that the sketch or drawing could be worked from. This is considered an important qualification for a first-class engineer, and as his sending home an unworkable sketch to replace a break-down would be a practical failure in competency, will fail the candidate.

The examination questions are designed to test the degree of knowledge of this kind possessed by the candidate, and thereby to ascertain how much his heart has been given to his work. The examination papers for a second-class certificate will consist of questions relating to the candidate's experience in the construction and management of engines, of questions in elementary knowledge, and of a set of engineering arithmetical questions.

In addition to these examination papers a candidate for a first-class certificate will have also another set of arithmetical questions, and an examination paper on indicator diagrams and working drawings. The first set of new questions for first-class require a knowledge of the strength of a shaft against twisting and against transverse breaking, the strength of an iron level, the loss by friction, and the cut off by a given amount of lap.

The new questions for second-class candidates contain nothing beyond what is contained in the old set of questions, except that one of the questions requires a knowledge of the weight of wrought iron. In addition to these examination papers, the *viva voce* examination papers will be continued as heretofore. These alterations are not intended in any way to remove from the individual examiner the entire responsibility of passing or of failing any candidate. The examination papers are planned to assist the examiner, and to afford a written evidence, to some extent, of the thoroughness of the examination, and to promote uniformity at the various examining ports.

ELEMENTARY QUESTIONS FOR ENGINEERS.

(*a*) Where and how long did you serve in works at the making or at the repairing of engines?

(*b*) How long have you served in the stokehole?

(*c*) How long have you served in the engine room at sea, and in what capacities?

(*d*) With what description of engines have you served at sea—paddle or screw, or both jet condensing, surface condensing, or non-condensing engines, compounds, trunks, inverted cylinders, or horizontal engines? What size were the engines?

(*e*) With what description of boilers have you served at sea—rectangular or cylindrical, wet bottomed or dry bottomed, multitubular, sectional, or flue boilers?

(*f*) What engine defects have come under your notice at sea, and what caused these defects, and how were they remedied? Give the names of the steamers for verification.

(*g*) What boiler defects have come under your notice at sea, what caused these defects, and how were they remedied? Give the names of the steamers for verification.

PROCEEDINGS OF UNITED STATES STEAMBOAT ACT.

RELATING TO LICENSED OFFICERS.

RULE 42.—Before a license can be issued to any person to act as a master, mate, pilot, or engineer, he must personally appear before some local Board, or a supervising inspector, for examination, according to the law; but upon the renewal of such license, when the distance from any local Board or supervising inspector is such as to put the person holding the same to great inconvenience and expense to appear in person, he may, upon taking the oath of office before any person authorized to administer oaths, and forwarding the same, together with the license to be renewed and Government fee, to the local Board or supervising inspector of the district in which he resides or is employed, have the same renewed by the said inspectors, if no valid reason to the contrary be known to them; and they shall attach such oath to the stub end of the license, which is to be retained on file in their office.

CLASSIFICATION OF ENGINEERS.

RULE 43.—The classification of engineers on the lakes and seaboard shall be as follows:

Chief engineers of ocean steamers.
Chief engineers of lake, bay, and sound steamers.
Chief engineers of river steamers.
First assistant engineers.
Second assistant engineers.
Third assistant engineers.
Special engineers.

All steamers of over one hundred tons burden shall carry at least one chief engineer.

First assistant engineers may act as first assistants on any steamer.

Second assistant engineers may act as first assistants on steamers of seven hundred and fifty tons and under, and second assistants on any steamer.

Third assistants may act as second assistants on steamers of seven hundred and fifty tons and under, and third assistants on any steamer.

Special engineers may be assigned to act, in any capacity for which they are qualified, on steamers of one hundred tons and under.

Inspectors may designate upon the certificate of any chief engineer the tonnage of the vessel on which he may act, and they may also designate any assistant engineer as special engineer on steamers of one hundred tons or under, and may restrict an engineer to a particular vessel.

Engineers on steamers navigating rivers flowing into the Gulf of Mexico, and into the Pacific Ocean, shall be designated as first and second engineers. The first engineer shall rank as a chief engineer. For steamers of one hundred tons or under, special engineers may be licensed, and may, at the option of the inspector, be restricted to a particular steamer.

First assistant engineers and second engineers may act as chief engineers and first engineers of steamers of one hundred tons burden or under.

Special licenses of all grades shall be regarded as of inferior grade, and the fee for the same in every instance shall be five dollars.

RULE 44.—The navigation of every passenger steamer above one hundred tons burden shall be under the control of a first-class pilot, and every such pilot shall be limited in his license to the particular service for which he is adapted. Special pilots may also be licensed for small steamers of all kinds locally employed.

On all waters other than rivers flowing into the Gulf of Mexico, second-class pilots may be allowed to take charge of steamers not exceeding one hundred tons burden, and may be authorized by the license granted to act in charge of a watch as assistant to a first-class pilot on freight and towing steamers of all tonnage.

Steamers navigating in the night time SHALL, *in addition to the regular pilot on watch, have one of the crew also on watch in or near the pilot house.*

RULE 45.—When an original license is issued to a pilot whose route extends beyond the jurisdiction within which the license is issued, it shall be the duty of the local Board issuing such license to refer it to the local Board of inspectors having jurisdiction over the remainder of his route, for their endorsement thereon.

This rule shall apply only to the seaboard, Gulf of Mexico, and rivers flowing into the Atlantic Ocean.

RULE 46.—On all rivers flowing into the Gulf of Mexico, (and their tributaries), where inspectors are called upon to extend a pilot's license beyond the usual route for which said pilot has been licensed, they may, on being fully satisfied, grant the same; or they may refer such application to the Board of the district to which the extension may be desired, for the purpose of obtaining an endorsement of such grant on such license.

RULE 47.—Inspectors, before granting or renewing a license to any person to act as a pilot, shall satisfy themselves, by examination, that he thoroughly understands the rules and regulations governing pilots.

Pilots of steam vessels, while in the discharge of their duties, must be governed by the Rules of the Board of Supervising Inspectors made for their guidance, and not by any instructions emanating from any inspector or other person.

RULE 48.—The grade of an engineer or pilot shall not be raised, during the time for which his license was granted, by any other than the inspectors who granted the same, nor by them unless proper reasons are given for the change.

The following formula shall be used by inspectors in determining the pressure to be allowed for rivetted cylindrical flues of sixteen (16) inches and upward, viz.:

$$\text{Let } \frac{1760}{D} = \text{a constant } (C).$$

D = Diameter of the flue in inches.
T = Thickness of flue in decimals of an inch.

FORMULA:—

$$\text{Constant } \frac{C \times T}{.31} = \text{lbs. pressure allowable.}$$

EXAMPLE.—Given a flue twenty (20) inches in diameter, and thirty-seven one-hundredths (.37) of an inch in thickness. Required, pressure to be allowed by the inspector.

$$\frac{1760}{D}=\frac{1760}{20}=88=\text{constant (C).}$$

$$\frac{C \times T}{.31}=\frac{88 \times .37}{.31}=104 \text{ lbs. pressure allowable.}$$

For cylindrical flues of less than sixteen (16) inches in diameter, the following formula for determining the pressure to be allowed, shall be used by inspector, viz.:

$$\frac{1760}{D}=\text{a constant (C).}$$

D=Diameter of flue in inches, and T=Thickness of flue in decimals of an inch.

FORMULA:—

$$\text{Constant } \frac{C \times T}{.25}=\text{lbs. pressure to be allowed.}$$

EXAMPLE.—Given a flue ten (10) inches in diameter, and twenty-two (22) inches in thickness. Required, pressure to be allowed by the inspector.

$$\frac{1760}{D}=\frac{1760}{10}=176=\text{constant (C).}$$

$$\frac{C \times T}{.25}=\frac{176 \times .22}{.25}=155+\text{lbs. pressure allowable.}$$

The following formulas shall be used by inspectors to determine the pressure allowable for cylindrical rivetted flues used as furnaces, viz.:

D=Diameter of flue in inches.
T=Thickness of flue in decimals of an inch.
L=Length of flue in feet (not to exceed eight (8) feet).
89600=A constant.

*FORMULA:—

$$\frac{89600 \times T^2}{L \times D} = \text{pressure to be allowed.}$$

EXAMPLE.—Given a flue of forty (40) inches in diameter, seven (7) feet long, and five-tenths (.5) of an inch in thickness. Required, the pressure to be allowed by the inspector.

$$\frac{89600 \times T^2}{L \times D} = \frac{89600 \times .25}{7 \times 40} = \frac{22.400}{280} = 80 \text{ lbs. pressure.}$$

Provided, That if rings of wrought iron are fitted and rivetted properly on, around, and to the flues, in such manner that the tensile strain on the rivets shall not exceed six thousand (6,000) pounds per square inch of section, the distance between these rings shall be taken as the length (L) of the flue in the formula:

EXAMPLE.—Given a flue forty (40) inches in diameter, eight (8) feet long, and five-tenths ($\frac{5}{10}$) of an inch in thickness, having one ring at the middle of its length. Required, the pressure to be allowed by the inspector.

$$\frac{89600}{L \times D} \times T^2 = \frac{89600 \times .25}{4 \times 40} = \frac{22.400}{160} = 140 \text{ lbs. pressure allowable.}$$

CHAS. C. BEMIS,
GEO. B. N. TOWER,
JOHN FEHRENBATCH.

*British Lloyds.

LIST OF BOOKS FOR ENGINEERS TO READ AND STUDY, ETC.

"CHIMNEYS FOR FURNACES, FIRE PLACES AND STEAM BOILER."

"STEAM BOILER EXPLOSIONS." BY L. COLBURN.

"A TREATISE ON COMPOUND ENGINES." BY TURNBULL.

"SAFETY VALVES." BY R. H. BUEL.

"FUEL." BY J. WORMOLD.

"ON BOILER INCRUSTATION AND CORROSION."

"STEAM INJECTORS." BY M. LEON POCHET.

"STEAM ENGINE CONSTRUCTION AND STRENGTH MATERIALS."

(50 cents each—publishe by VanNostrand & Co., New York.)

SCIENCE PRIMERS.

"CHEMISTRY." BY PROF. ROSCOE.

"PHYSIC OR NATURAL PHILOSOPHY." BY B. STEWART.

(35 cents each—published by McMillan & Co., London.)

"REED'S ENGINEERS' HANDBOOK."

"HASWELL'S ENGINEERS' HANDBOOK."

"CATECHISM MARINE STEAM." BY E. EDWARDS.

"EVER'S MARINE ENGINEER."

"THE GROWTH OF THE STEAM ENGINE." PROFESSOR THURSTON.

"A TEXT BOOK OF THE STEAM ENGINE." T. M. GOODEVE.

"PROPORTION OF THE STEAM ENGINE." PROFESSOR GRIMSHAW, M. E.

"MECHANICAL ENGINEERING. BY D. K. CLARK.

"APPLETON'S APPLIED MECHANICS."

"A TREATISE ON THE STEAM BOILER." R. WILSON.

"USEFUL INFORMATION FOR ENGINEERS." FAIRBAIRN.

"STEAM ENGINE." BY PROF. RANKINE.

"EXPERIMENTS ON IRON." KIRKAEDY.

"MECHANICS OF ENGINEERING." BY MOSELEY."

"FRICTION AND LUBRICATION." BY PROF. THURSTON."

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