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SMOKELESS HEAT

A PRACTICAL TREATISE

WITH IMPORTANT FORMULÆ AND INFORMATION

MARCH, 1898.

THE GENERAL ENGINEERING COMPANY

OF ONTARIO (LIMITED)

80 CANADA LIFE BUILDING, TORONTO

PRICE, 75 CENTS.

Imrie, Graham & Co., Printers, 31 Church St, Toronto.

PREFACE.

IT is over 100 years ago since the first mechanical stoker was made. In 1785 James Watt patented a device for pushing the coal from the front end of the grate, after it was coked towards the bridge wall. It was worked by levers and the prime object was to prevent smoke when using bituminous screenings.

Since then the best inventive genius in the world has been striving to perfect a smokeless furnace. The number of smoke prevention devices which have been invented is legion, and the number of failures also legion, and it was not until the Jones Underfeed Mechanical Stoker was put on the market that a truly smokeless and economical device was obtainable. All other devices, such as steam jets, down draft and similar makeshifts, which are dependent upon the skill with which they are operated, being more or less failures and certainly far from being economical or satisfactory.

In all power plants where steam is used the greatest economy should be observed in the boiler-room, and as it is a well known fact that there is a difference between good firemen and coal shovellers of about 40% in the coal consumption for certain results, it stands to reason where skilled labor is very scarce the coal consumption must be higher than it otherwise would be.

In presenting this small treatise to the public we wish to thank those who have appreciated the value of the Jones' Stoker by having their plants equipped with them, and also to the engineers and firemen who have had the practical working of them, and who by simply giving their **honest opinions** as to the merits of the device have assisted in establishing its reputation.

Where intelligence is associated with the stoker the results cannot be approached by any other device. 'Tis true that the Jones can be made to smoke, yet this can **only** be done by gross carelessness, inattention, or by design, whereas with other so-called smoke consumers it takes the greatest of skill and hard labor to make the chimney **smokeless**, even for a short time.

We have endeavored to describe the Improved Jones Underfeed Mechanical Stoker in the following pages, for which all of its users claim the highest possible results, the device ranking at the head of all the wonderful inventions of the day. No steam plant is complete without it, no manufacturer in close competition can afford to leave his plant unequipped with this preventor of waste and saver of money.

Content to let our work in this line speak for itself through the practical medium of the Stokers installed during the past four years, we ask nothing further than an **unbiased investigation** of the records made thereby.

Outside of describing the Stoker we have included in our treatise important and useful information and formulæ, which all engineers will appreciate. The Historical Chapter will also be found interesting, as it traces from B.C. down to the present time, in chronological order, the different stages the steam engine has gone through to make it what it is to-day. We have also added some forty questions which engineers will find to their interests to work out.

J. M.

OUR BUSINESS POLICY

is to undertake ONLY such construction as will insure reliability, permanency and economy.

OUR EXPERIENCE

has been of such practical nature as to enable us to avoid engineering errors frequently made by less experienced engineers.

WE ADVISE OUR CLIENTS

only after thoroughly investigating ALL the conditions which exist.

WE CONTRACT

for the complete installation of high grade plants of all descriptions, electrical and mechanical.

WE SUPERVISE

the installations of plants of all descriptions. Since we have absolutely no connection with any manufacturers or agents we can furnish

INDEPENDENT ADVICE

which is a matter of very great importance in these days.

WE ARE PREPARED

to decrease expenses in many power plants in operation.

WE DON'T EXPERIMENT

at the cost of our clients. We have got over the experimental stage. New methods are only adopted after every possible argument for or against has been brought forward.

WE DO NOT

jump at conclusions.

MISTAKES COST MONEY

Then to avoid mistakes

CONSULT US

for all **you want to know** on any engineering subject electrical, mechanical, or otherwise.

THE GENERAL ENGINEERING CO.

OF ONTARIO, (LIMITED)

HEAD OFFICE—90 Canada Life Building,

TORONTO, ONT.

HISTORICAL.

927 B.C.—Homer spoke of steam as we do.

390 B.C.—Plato described steam as water melted into air by heat, which could be compressed into water again.

222 B.C.—Archimedes is said to have used steam in his defensive engines.

150 B.C.—Hero is associated with the invention of the steam engine although it appears to have been known 1,000 years before his time. He invented hot air, rotatory and idolatrous engines.

1543.—DeGary, a Spanish captain, proposed to propel ships by steam.

1601.—Porta, the inventor of the magic lantern, showed the relative volume and force of steam in raising water.

1612.—De Caus showed the power of the sun on confined water by lenses, to increase the sun's effect, water was forced up six feet in pipes.

1618.—David Ramsay obtained a patent for an engine to plough without horses, to raise water and propel ships and to raise water by fire from deep pits, move ships against wind and tide, and to fertilize the earth.

1629.—Branca describes a rotary steam engine he used for grinding drugs.

1648.—The suggestion of flying by high pressure steam and large wings was made.

1651.—Marquis of Worcester pumped water by steam engine.

1702.—Savary states, "My engine raises a full bore of water sixty or seventy feet high, and if strong enough I would raise water 500 to 1,000 feet high." Savary was the first to use gauge cocks. It is related that Savary accidentally discovered the force of 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.

1705.—Newcomen employed the air to perform the work of pumping water and steam only used as an auxiliary. Newcomen, by condensing the steam below the piston forced it and that end of the beam down, whilst the elevation of the other end raised water from the mine. Steam was therefore used merely to raise the piston, and air to do the work.

1740.—Experiments made at Newcastle are said to have realized an evaporation of eight pounds water for one pound coal.

1757.—Fitzgerald added the fly-wheel to the engine.

1762.—Dr. Black investigated the properties of heat and steam and propounded the doctrines of latent heat.

1766.—Blakely introduced tubular boilers.

1770.—Cugnot, French engineer, made a model of a steam locomotive, and the French Government constructed one at the Paris arsenal and tried it in 1771, and then "laid it aside."

1772.—Smeaton determined the relative steaming values of different coals. Smeaton realized a duty of 112,500 foot pounds for one pound coal.

1730-1819.—The great defect of Newcomen's engine as improved by Smeaton was the loss of heat arising from condensing the steam in the working cylinder. James Watt estimated this to be nearly 35%, and in

1769.—Watt patented the addition of a separate condenser.

1782.—Watt invented the double acting cylinder, using steam on both sides of the piston.

1799.—Watt's assistant, Murdock, introduced the eccentric and slide valves. Watt invented the governor and throttle valve. To overcome a patent unfairly obtained through one of his workmen, Watt invented and used the

1780.—Sun and planet wheels in place of the crank. Watt claimed the crank was part of his design, but to avoid litigation used this arrangement.

1776.—Watt introduced the expansion of steam. He calculated when cut off at half stroke the performance would be as 1.7, at ¼ stroke as 2.4, and at 1/7 as 3 in economy as compared with steaming the whole stroke. Watt was the first to recognize fully the importance of gaining some knowledge of the action of steam in the cylinder and the first form of an indicator was the result of his efforts.

1776.—Bushnell proposed a screw propeller for ships.

1778.—Watt erected at Shadwick waterworks, an engine working expansively.

1780.—Watt by improved flue and other arrangements obtained 8.6 pounds evaporated water per pound coal, or nearly 10% better than Smeaton.

1781.—Hornblower patented the same principle, expanding the steam into a second cylinder which led

1782.—Watt to patent his single cylinder plan of expansion. It cost Boulton, Watt's partner, $400,000 to defend his patent rights and introduce his engines before any profit was realized.

1784.—James Rumsy exhibited on the Potomac a boat propelled by machinery. He exhibited a boat in which a pump worked by steam power drove a stream of water from the stern and thus furnished the motive power.

1786.—Symington tried to combine Newcomen's atmospheric engine with Watt's separate condenser, yet evade the patent, but failed to do so. Symington constructed the first paddle wheel steamboat of the modern class.

1791.—Street dropped turpentine on hot iron and exploded the vapour formed below a piston to produce motion.

1797.—Cartwright used metallic packing.

1790-1816.—Trevethick erected in connection with Watt's former workman, Bull, several engines with double-acting cylinders. This able engineer introduced high pressure steam and expanding to a low pressure. So marked was the economy that the Court of Spain sent him with regal honours to the silver mines in Peru to drain them.

1800.—Bell fitted a four H. P. engine in a small vessel and sailed from the Clyde to the Thames at seven miles an hour.

1802.—Trevethick patented a road locomotive which was successfully tried near Londen.

1804.—Improving on this he completed a locomotive to draw coal. It worked well, drawing ten tons of iron at five miles an hour. Trevethick was the inventor of the first modern locomotive.

1804.—Oliver Evans showed wonderful grasp of the science, but for want of money he could not carry out his ideas. He used the exhaust steam to heat the feed water, he worked with

The Improved Jones Underfeed Mechanical Stoker
and Smokeless Furnace.

high pressure steam. In the writer's opinion Evans has not got the credit he deserves.

1804.—Stevens, of Hoboken, with a Watts engine 4½ x 9 supplied with steam from a boiler consisting of eighty-one horizontal copper tubes one inch diameter and two feet long propelled a steamboat four miles an hour by a screw.

1793-1807.—Fulton successfully introduced steam boilers on the Hudson.

1815.—Ralph Dodd put a fourteen H. P. engine into a seventy-five ton boat and made a trip of 758 miles in 122 hours in very stormy weather.

1807.—M. DeRevax moved a locomotive carriage by exploding a mixture of hydrogen and air in a cylinder by electricity.

1813.—Blackett demonstrated that the enormous weight of the adhesion between the smooth rails and the equally smooth wheels would suffice to prevent the wheels of a locomotive from slipping.

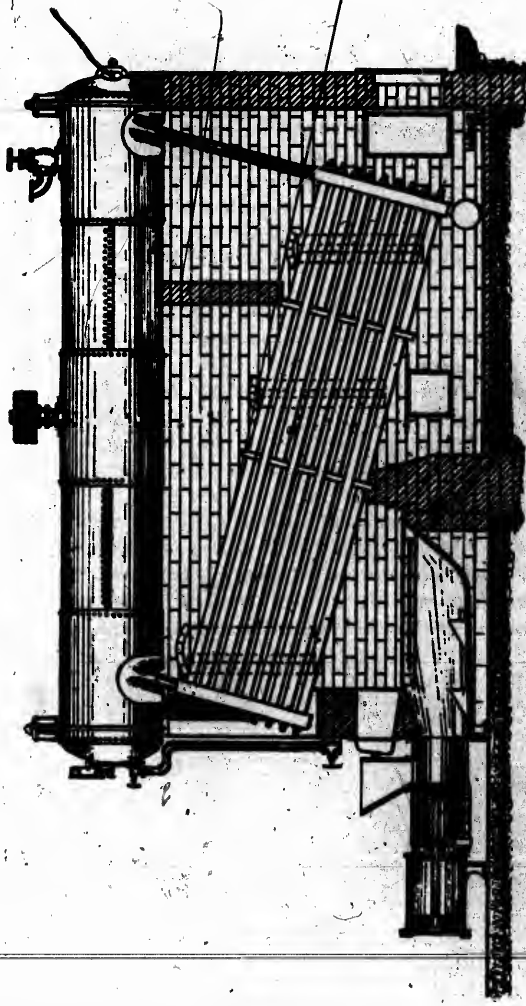
1814.—George Stephenson ran his locomotive "Blucher" on the Killingworth railway.

1818.—Napier successfully prosecuted steam navigation and in

1822.—The "James Watt" of 100 H. P. and 440 tons burden ran from Leith to London at ten miles per hour.

1824.—Brunel tried a carbonic acid gas engine

1829.—Stephenson obtained the prize of £500 for constructing and running his locomotive "Rocket" over a distance of thirty miles in two hours and seven minutes. This test was between the "Sanspareil" built by Hackworth, and the "Novelty" built by Ericsson, and was to be a run of thirty miles at not less than ten miles per hour backward and forward along a mile level with a load three times the weight of the engine. The "Novelty" after running twice along the level was withdrawn, owing to the failure of the boiler plates. The "Sanspareil" traversed eight times at a speed of nearly fifteen miles an hour and was stopped owing to the machinery being deranged. The Rocket was the only one to stand the test. The maximum speed was twenty-nine miles per hour and the minimum twelve. One of the conditions of this test was the



Improved Jones Stoker as Applied to Babcock & Wilcox Boiler.

locomotive had to consume its own smoke. Owing to the fact that the Improved Jones Underfeed Mechanical Stoker was not on the market at this time the smoke was overcome by burning coke. Stephenson made a splendid reputation, and projectors of all kinds, together with young men, asked his advice and counsel. This he gave cheerfully, except when these youths were "affectedly dressed," and put on "airs" contrary to his notions of propriety. To one youth applicant of this stamp he said: "I hope you will excuse me, I am a plain-spoken person, and am sorry to see a nice-looking and rather clever young man like you disfigured with that fine patterned waistcoat and all these chains and fang-dangs. If I had bothered my head with such things when at your age I should not be where I am now."

1829.—Ericsson introduced hot air as a competitor with steam.

From 1829 until the present date the history of the locomotive is a vast series of improvements in details, far too various and numerous to mention here, until now it is one of the most perfect and beautiful of all the machines with which the engineer has to deal, and of which he is justly proud.

1889.—**Jones invented the Underfeed Stoker, an invention which ranks at the head of all the wonderful inventions of the day.**

NE PLUS ULTRA.

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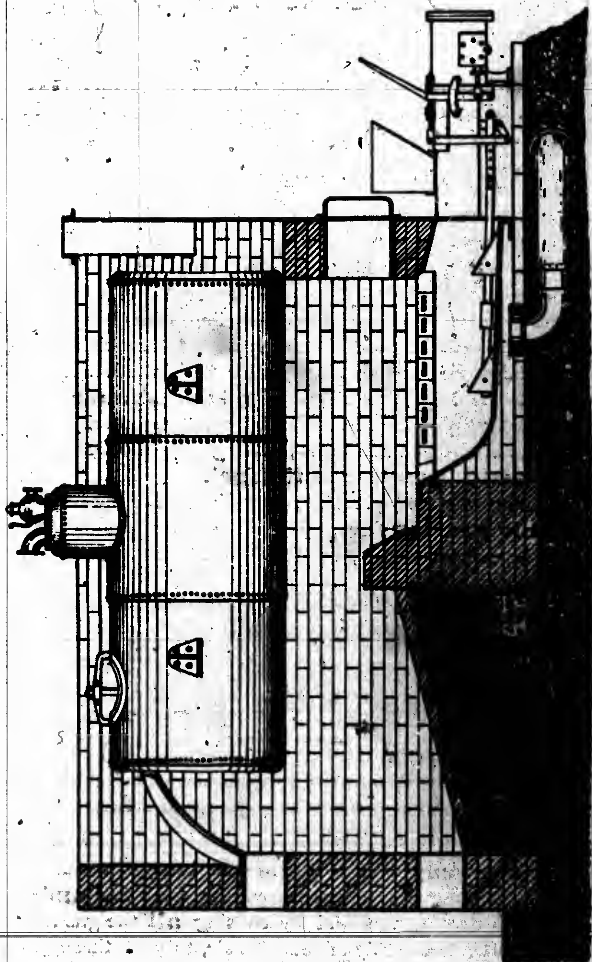


Improved Jones Underfeed Stoker as Applied to Tubular Boiler

DESCRIPTION.

THE Stoker consists of a steam cylinder or ram, with Hopper for holding the coal, outside the furnace proper, and a Retort or Fuel Magazine, inside the furnace, into which the green fuel is forced by means of the ram; Tuyere Blocks, for the admission of air, being placed on either side thereof; the Retort containing at its lowest point, and, at a point where the fire never reaches, an auxiliary Ram or "Pusher" by means of which an even distribution of the coal is obtained.

By means of the rams, coal is forced **underneath** the fire, each charge of fuel raising the preceding charge upward, until it reaches the fire; which point it does not reach until it has been thoroughly coked, when in its coked state it is forced upward into the fire. The gases being liberated **under** the fire, and at that point mixed with air, must necessarily pass through the fire and be consumed, thus giving the benefit of **all combustible matter in the fuel.**

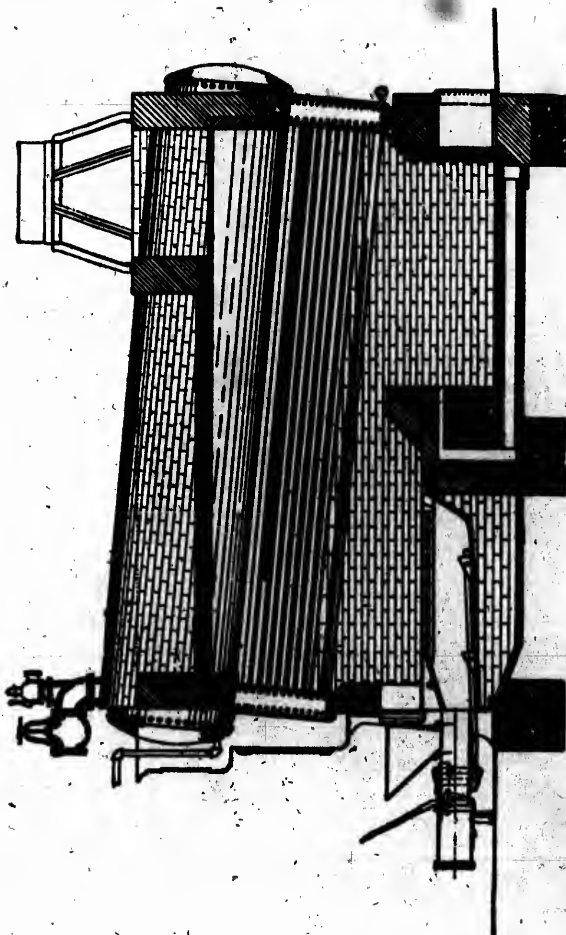
Air is forced, at a low pressure, through the Tuyere Blocks, **under the burning fuel**, by means of a Blower, operated by an independent engine, or from a line shaft, if such arrangement can be made.

Your attention is called to the illustrations herein, showing the Stoker and its application to different types of boilers.

Features of the Stoker.

THERE are some desirable points in the construction and operation of the Improved Jones Underfeed Mechanical Stoker that are appreciated by the engineer and firemen and the man who pays for the coal.

FIRST. **Economy** in the use of fuel brought about by liberating **all** the gases from the fresh fuel **under** the burning fuel and by causing **all** the gas from same, thoroughly mixed with air, to pass through a body of burning coke at a high temperature thereby



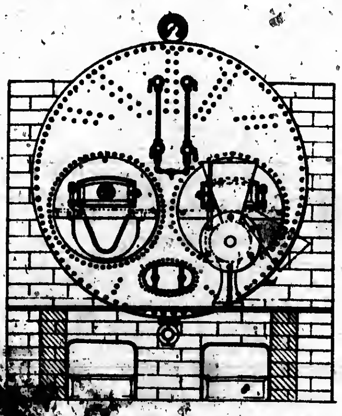
Improved Jones Underfeed Stoker as Applied to Heine Boiler.

consuming all the heat producing elements, and also by avoiding the waste of small particles of unconsumed fuel that unavoidably pass through the ordinary grate bar.

SECOND. **Adaptability.** A furnace adapted to the use of any kind of fuel and **more especially screenings and other fine fuel.** A furnace applicable to any kind of boiler, land or marine.

THIRD. **Durability.** A furnace without any moving parts subject to the action of the fire. A furnace which does not cost so much for repairs as ordinary grate bars. A furnace which is as durable and more so than fire brick itself.

FOURTH. **Simplicity.** A furnace that can be operated by any one of ordinary intelligence. A furnace that is under complete control at all times. A furnace that can be fired by hand at any time without change in the ordinary manner. A furnace in which the only mechanical movement consists of a plain cylinder



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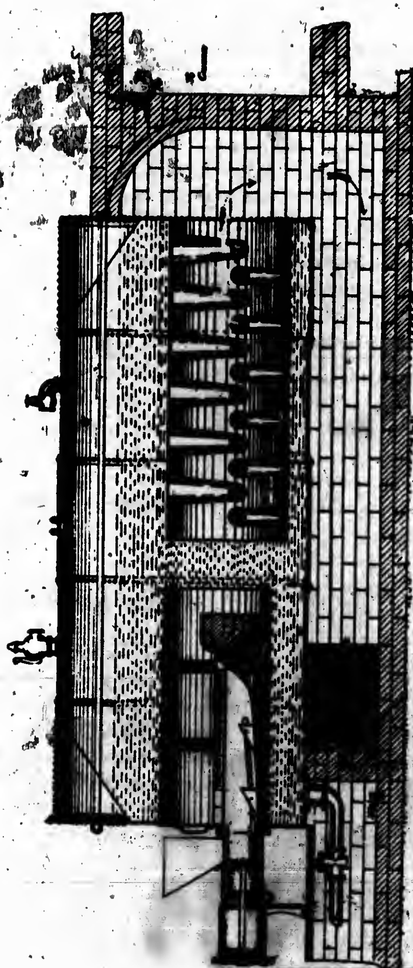


Improved Jones Underfeed Stoker as Applied to Galloway Boiler.

and piston entirely outside of the furnace, "getatable" at all times. A furnace of few parts and of solid construction.

FIFTH. **Capacity.** A furnace that can increase the steaming capacity of the boiler from 50 to 75% above its rating with the poorest quality of coal, and with good economy. A furnace that can increase the steam pressure instantly, no matter what the circumstances are.

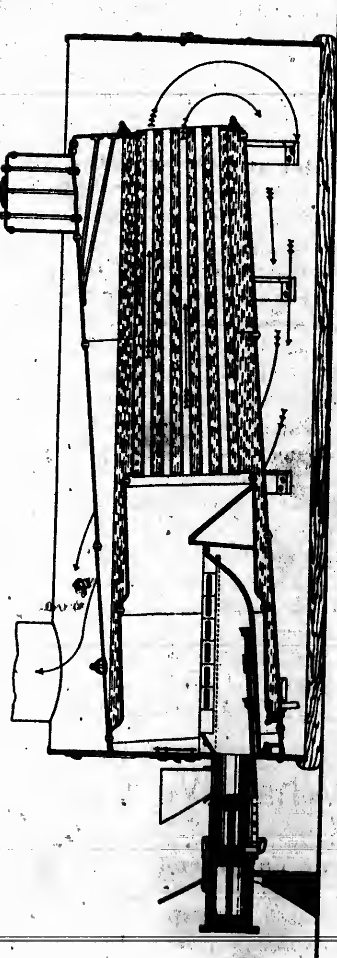
SIXTH. **Smokelessness.** A furnace that gives a practically smokeless stack without skilled labor. A furnace that enables the flues to be kept cleaner, there being no smoke.

SEVENTH. **Combustion.** A furnace in which the proper quantity of air can always be diffused through the burning coal, thereby producing perfect combustion. A furnace in which the escaping gases are only a few degrees **above** that of the steam. A furnace in which the coal is put **where** and **when** it is needed.

Operation of the Jones Stoker.

WE will suppose that the furnace is being fired without steam in the boiler. The retort is first filled with coal, level, or a little above the tuyere blocks. Fire is then started by placing kindling or greasy waste, lighted, along each side of the retort and opening wide the air chamber reaching to the tuyere blocks. As soon as sufficient steam is raised to run the blower, air chamber opening is closed, blower is used for furnishing air; and fire will be built up very rapidly.

Coal being in the hopper, and the ram plunger at its forward stroke, when more coal is needed the ram plunger is shifted by moving the lever; coal then falls in front of plunger and upon return movement is forced into the retort, this movement being repeated until sufficient fuel is in the retort. After fire is



Improved Jones Underfeed Stoker as Applied to a Monarch Economic Boiler.

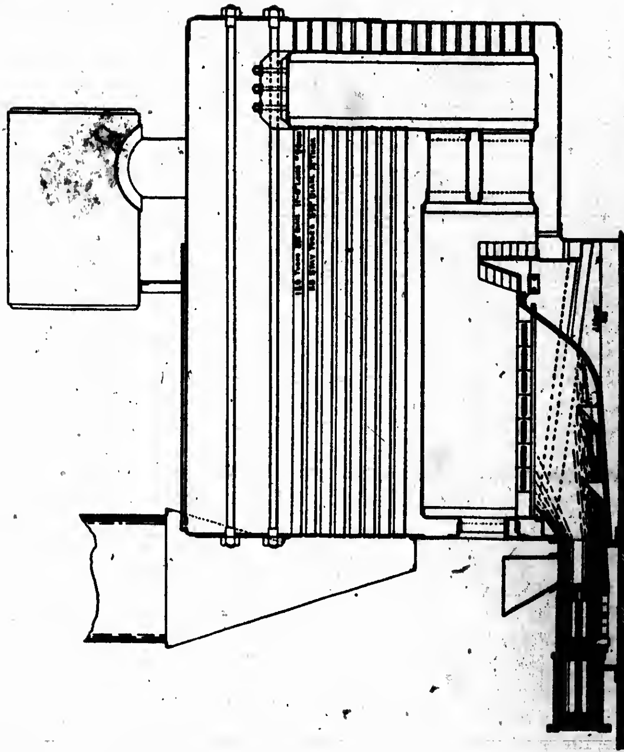
properly started, **never make more than two charges of the ram at a time**, as by so doing green coal is forced into the fire, which will produce imperfect combustion and consequently smoke.

Air, at low pressure being admitted into the air chamber and through the tuyere blocks, over the top of the green fuel in the retort, but **under and through the burning fuel**; the result is that the heat from the burning fuel over the retort slowly liberates the gas from the green fuel in the retort. This gas being thoroughly mixed with the incoming air before it passes through the burning fuel above, results in a bright, clear fire, **free from smoke**, and the complete consumption of all the heat-producing elements in the fuel. The retort being air tight from below, and the fuel being in a compact mass in the retort, the air will find its way in the direction of the least resistance, which is upward, consequently combustion takes place only **above** the air slots, hence the castings of the retort are always cool and not subject to the action of the fire. The incoming fresh fuel from the retort, forces the resulting ash and clinker over the top of the tuyere blocks on to the side plates, from whence they may be removed at any time without in the least interfering with the fire in the centre of the furnace, resulting in a high, even temperature at all times.

To secure the best results a heavy body of coke should at all times be carried in the furnace, as nearly like the illustration as possible. The amount of coal consumed is regulated entirely by the quantity of air forced in the furnace, so that when little steam is needed the quantity should be reduced.

What We Claim.

AS we intend to be conservative in all our estimates, and as **we do not intend** to make any promises that we cannot fulfil, before we can set forth our claims regarding any particular plant, it will be necessary that we know all the conditions under which the plant is operated. To this end we invite correspondence or a personal interview from all parties operating steam plants of any kind, believing that we can show



Improved Jones Underfeed Stoker as Applied to Marine Boiler.

you that it will be to your interest to at least give our device a careful investigation.

It is not safe to assume that we can show the same comparative results in all cases and under all circumstances. We will say in a general way, however, that in plants already equipped with our device, a saving of from **ten to forty per cent. has been shown**, depending upon various conditions.

We will state, moreover, that our device will burn any kind of bituminous or lignite, slack or screenings, and will fully utilize **all** the heat-giving elements therein ; and that, whether good coal or refuse slack, or screenings are used, our device insures a substantially smokeless stack.

Our device, furthermore, will increase the capacity and efficiency of your boilers, and by its even and non-fluctuating heat saves wear and tear of the boilers and adds to their durability. The use of the device requires no change in the boiler proper, the only change being in the furnace. If you are equipping a new plant your furnace can be arranged to accommodate our device without any additional expense over what it costs to arrange it to receive common grates for hand firing, and sometimes less.

We Base Our Claims on the Following Grounds:

Ours is the only furnace designed and constructed upon thoroughly scientific principles ; it is the only one in use in which the gas from the green coal is liberated **under** a mass of **incandescent coke**.

This gas, after being thoroughly **mixed** with the **proper** amount of **air**, is caused to pass **up** and through this intensely heated body. Can you imagine a more simple or a surer plan of burning all the gases, as well as all the coke, thereby securing all the **heat** there is in the coal?

In other words, in the arrangement of our fire the green coal is always covered with a body of incandescent coke, the heat from which generates the gas from the green coal, and as fast as it is generated we **force** the **proper** amount of **air** over the **top** of the green coal, but **under** the coke. The result is that a **mixture** of air and gas takes place under the coke,

Cross Section Showing Furnace in Operation.

and as it passes **through** the coke is brought to a high temperature. A combination of the oxygen of the air and the gas from the coal takes place at once under the most favorable conditions; the result is that the **incandescent coke** generates the gas, and the gas, after its mixture with the air, burns the **coke**. Hence we feel justified in claiming that it is the **simplest** and most **economical** combined gas producer and consumer in **one fire box**.

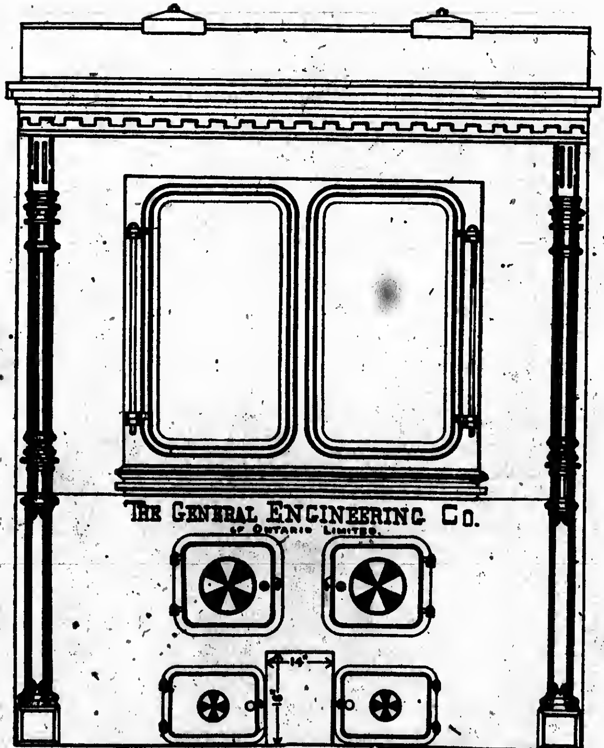
Competitive vs. Ordinary Tests.

IN making comparisons between mechanical stokers and hand firing the conditions should be kept as nearly as possible the same as during ordinary running. With stoker firing as far as ordinary running and competitive tests go the results are practically the same, there being not one per cent. difference, whereas with hand firing there is at times over 20%.

In **competitive** tests the Jones Underfeed Stoker fired boiler in almost every case shows 15% better results over the very best hand firing and with ordinary conditions the results are from 20 to 35% better than hand firing.

It is the ordinary running that counts, not the competitive test, made for a few hours only and can't be kept up. A good fireman is worth his salary, and a good one at that, but there is a vast difference between a good fireman and a coal shoveller. The latter being more numerous, as a matter of fact, than the former. The great difference shows up monthly in the coal bill. Good firemen are scarce, very scarce, therefore knowing that, you can readily understand that the average results obtained from indifferent firemen will certainly be poor.

As already stated there is a difference between the Jones Underfeed Mechanical Stoker and exceptionally good firing of about 15% in favor of the Stoker, and between ordinary and good hand firing also 15%, and between ordinary and poor hand firing we have at least 10%, making a difference between the Jones Underfeed system and **poor hand firing** of 40%, which is actually the case.



Size of Opening in Boiler Front to Receive the Jones Stoker.

With hand firing it is possible to get fair results if the boilers are run just to their rating, but if you try to force them the evaporative results are exceedingly poor. With the Stoker, on the other hand, it is a comparatively easy matter to force the boiler from 50 to 75% above its rating with exceptionally good results. From this you will see that in power plants where the load is of a fluctuating nature the Stokers are indispensable. **It is the ordinary running that counts.** A test is only for, say, twenty-four hours; ordinary running continues for 365 days a year.

High Chimneys With Natural Draft, vs. Jones Underfeed System.

HIGH chimneys have been truly characterized as "monuments of folly," and are absolutely unnecessary in plants fitted with the Jones Underfeed Stokers.

Let us consider the difference in cost between two power plants say of 2,000 H. P. one with high chimney, natural draft, and plain furnaces, and the other fitted with the Jones Underfeed Mechanical Stokers. The cost of the first plant exclusive of the building would be approximately (ten boilers, including setting, $36,000, and the chimney say 100 feet high by seven in diameter) $40,500. In the second plant it is necessary to put in only eight boilers to get the same results as far as power is concerned, leaving out of the question for the present the increased efficiency, and a short stack of from twenty to thirty feet high being sufficient The cost of the eight boilers, including the setting, would be $28,800, and this, together with the Stokers and the chimney, makes a total of $35,800, or a saving in the first cost of $4,700, which is more than the cost of the chimney. There is also a reduction in interest, taxes, etc., which must be placed to the Stoker's credit. There is also a reduction in boiler repairs which will more than offset the cost of operation of the Stokers. We come next to the saving of coal effected by the Stokers. Taking our plant as above specified, ten boilers burning say 400 pounds per hour each, amounting to twenty tons per day of ten hours with hand firing against eight boilers burning the same quantity per boiler

Terauley St. Station, Toronto Electric Light Co.

per hour for the same results = sixteen tons daily, or a daily saving of four tons, equal to over $3,000 yearly. We have, therefore, a saving in first cost of $4,700, and a yearly saving of over $3,000, which is certainly worth while considering.

These figures are very nearly correct, for it has been proved over and over again that in ordinary running the Jones Stoker shows an increased efficiency over hand firing of 20 to 40% and 50% more work; and when this is actually the case it clearly shows that in the above plant the number of boilers could have been reduced still further with perfect safety in the Stoker plant.

Heat Without Smoke

By the Improved Jones Underfeed Stoker and Smokeless Furnace.

HAND-FIRING is practically the same to-day as it was 100 years ago. If firemen are very careful to open and close the doors quickly and put on small quantities of coal at a time and use **good lump coal,** smoke **may be lessened** to some inappreciable extent if the boilers are run **below** their rating. If, however, they are run up to and over their rating, no fireman can be procured to fire as above, it being an impossibility for any one to endure it. Down draft furnaces are fired by hand, so are shaking grates, but they don't lessen the smoke any nor do they increase the economy, and furthermore, you cannot increase the capacity of your boilers unless you use the very best quality of coal. Down draft furnaces do not lessen the labor one iota; experience confirms this, and common sense does the same. Shaking grates, when new, may, to some extent, decrease the work of the fireman, but generally, at a critical time, when you **want** to shake them, you are unable to do so.

With all the numerous makeshifts, the greatest skill must be exercised to prevent smoke for even a very short time, and it goes without saying that it cannot pay any one to attempt smoke prevention with any of these devices in conjunction with hand-firing.

Orillia Asylum. Eight Jones Underfeed Stokers installed for Ontario Government.

There are "Stokers" and "Stokers," "furnaces" and "furnaces," but there is only one Underfeed Stoker and Smokeless Furnace, and that is the **Jones**. The principle of the Jones is admitted, by the most eminent authorities, to be scientifically correct, the principle being (1) the green coal is forced underneath, (2) air is admitted at a point **over** the top of the green coal but **under** and **through** the burning fuel, (3) the gases are slowly liberated from the green coal by the intense heat above, (4) the gases are **thoroughly** mixed with the air and (5) pass through the burning **coke** above. Can you think of anything more perfect than this? It is true, in a measure, that the Jones can be made to smoke, but this can only be done by **gross carelessness** and **inattention**, or by **design**, which is in marked contrast to all other devices which are only smokeless for a moment.

From 100 lbs. to 1200 lbs. coal per hour can be burned with the greatest economy with one stoker, **without smoke**, which in some cases would amount to over 40 lbs. per sq. ft. of grate surface per hour. This amount cannot be burned economically on hand-fired furnaces with natural draft, the half of this quantity being about the average for good results.

In the Jones Furnace after the heat is taken out of the coal, there is absolutely nothing left except clinker, the clinker resembling slag, no combustible, no ash. Is it possible to get any other device to do this? If there is we would like to know it. Owing to the fact that about 30% less air is required with this furnace than in ordinary hand-firing, the volume of heated gases passing up the chimney is decreased and the velocity of the gases is also reduced, allowing more time for the absorption of the heat by the heating surface of the boiler.

The temperature of the fire is a maximum while that of the escaping gases is a minimum, showing that **all** the heat is taken from the coal and transmitted to the boiler.

In a test made by the Engineering Department of the University of Michigan at the Varyan Plant, Toledo, Ohio, the temperature of the escaping gases was 346.3 Fah. in one case, and 331.6 Fah. in another, while that of the steam was 307.45 degrees Fah. and 330.2 degrees Fah. respectively. At the Riordon Paper Mills, Merritton, Ont., the temperature of the gases in the uptake was 365 degrees Fah., and that of the steam was 337.86 degrees Fah.

From the above can quite readily be deduced the fact that economizers are an unknown quantity in plants where the Jones Underfeed Furnaces are employed. In one plant, before the furnaces were installed, the escaping gases in the breeching had a temperature of 800 degrees Fah., and since their installation has been reduced to below 400 degrees. The effect of this must certainly show somewhere, and so it does, viz., in the coal bill.

Owners of plants who can afford the Jones Furnace should not be without it, whether they desire the smoke abated or not. The great saving justifies the expenditure; and if you are only burning 1200 lbs. per day of ten hours it **pays to put it in.**

The Jones Underfeed Stoker is absolutely smokeless except when cleaning fires and most excessive forcing. What is meant by excessive forcing is running a boiler from 75 to 100% above its rating, which can quite readily be done by the Jones'. **In ordinary working there is no smoke.**

The "Consumption of Smoke."

MUCH has been spoken and written on this subject, but practically nothing has been done. At one time it was the general belief that this could be accomplished, but after years of experimenting, and a multitude of devices have been examined and the most promising tried, with the popular conclusion that smoke consumption is a delusion, and further, that **economical** consumption of smoke is practically impossible. When smoke is once formed the cost of burning it far exceeds the value of the heat that is produced by the combustion of its flimsy flocculi of carbon. It is a fiend that once raised cannot be exorcised, a Frankenstein that haunts its maker and will not be appeased. The common idea is that if the smoke be carried back to the fire that produced it, and made to pass through it again, a re-combustion or consumption of the smoke will take place. This is a mistake, as a little reflection will show. First, let us ask why did this particular fire produce smoke? Everybody nowadays can answer this question, as we all know that smoke is the result of imperfect combustion, and knowing this it can readily be understood that to return the carbonic acid gas and excess of carbon to the already suffocated fire can only add smother ~~and~~ to smotheration and make the smoky fire more smoky still. There is, however, one case in which a fire appears to thus consume its own smoke, but the appearance is delusive. We refer to the fire being lighted from above as in the Jones Stoker. That is practically **smokeless,** and it is commonly supposed that smoke passes from the raw coal below through the burning coal above and is thereby consumed. The fact is, however, that **no** such **smoke is formed.** That which under [these conditions comes from the coal beneath, when gradually heated by the fire above is combustible gas and this gas is burned as it passes through the fire. In this case the formation or non-formation of smoke depends mainly on how this gas is burned, whether completely or incompletely. If the air supplied for its combustion is insufficient, smoke will be formed as it is when we turn up an Argand gas flame so high that the supply is too great in proportion to the quantity of air that can enter the base of glass chimney. Herein lies the fundamental principle. We may **prevent** smoke though we cannot **cure** it, and this prevention depends on how we supply the air to the gas which the coal gives off when heated and upon the condition of this gas when we bring it in contact with the air by which its combustion is to be effected. We must always remember that coal when its temperature is sufficiently heated, whether in a gas retort or on a fire-place, gives off a series of combustible hydrocarbon gases and vapors, and all we have to do in order to obtain smokeless fires is to secure the complete combustion of these. Now we know that to burn a given quantity of gas we must supply it with a sufficient quantity of oxygen, i.e., of the active principle of the air; but this is not all. We all know well enough if cold coal gas and cold air be brought together in any proportion whatever, no combustion occurs, a certain amount of heat is necessary to start the chemical combination of oxygen with hydrogen and carbon, which combination is the combustion, or burning. Therefore, when the coal gas and the air are brought together, one or the other, or both, must be heated to a certain point in order that the combustion be complete. If cold there is no combustion ; if insufficiently heated there is imperfect combustion, however well the supplies may be regulated. A very simple experiment that anybody may make illustrates this. When an ordinary open fire is burning brightly and clearly, without flame, throw a few small pieces of raw coal into the midst of the glowing coals. They will flame fiercely but without smoking. Then throw a heap of coal or one large lump on a similar fire. Now you will have dense volumes of smoke and little or no flame, simply because the cooling action of the large bulk of coal in the course of distillation brings the temperature of its gases below that required for complete combustion. This simple experiment supplies a most important practical lesson, as well as a philosophical example.

The best of all smoke abatement machines needs an intelligent and conscientious fireman, and every contrivance for smoke abatement must, in order to be efficient, either be fed by such a fireman or provided with some mechanical arrangement by which the apparatus itself does the work of such a stoker by supplying the fresh fuel just where it is wanted, and in the Jones Stoker we have just such a device, the coal fed from below, the gases from the raw coal uniting with the air and then the combination passing through an incandescent bank of fire, where the result is nothing more or less than complete combustion, for the temperature of the combined gases will be raised to the required degree and none can escape unconsumed. Thus not only the prevention of smoke is consummated, but large savings are made by burning all the gases that otherwise escape up the stack.

We will now conclude by saying that "smoke abatement" is to be achieved, **not by smoke consumption, but by smoke prevention.**

Horse Power.

WHAT is technically spoken of among Engineers as a horse power is the rate of doing work corresponding to 33,000 foot pounds of work, i.e., 1000 lbs. lifted 33 ft. in one minute, and the power of engines is always calculated on this basis.

Watt proposed this unit, and his method of arriving at it was as follows :—He took the ordinary London dray horse and found that it could do about 22,000 foot lbs. work per minute, and being an honest man, like **all** good Scotchmen, anxious to give the purchasers of his engines good value, added 50% to the amount.

The horse power exerted by an engine is equal to the total mean pressure on the piston in lbs. multiplied by the distance in feet travelled by the piston in one minute divided by 33,000.

Let H.P. = Indicated horse power.
N. = No. of strokes per min. = revs. × 2.
L. = Length of stroke in feet.
A. = Area of cylinder in square inches = diam.² × .7854.
P. = Mean effective pressure in lbs. per square inch.
P. × A. = Mean pressure on the piston.
L. × N. = Distance travelled by piston in one minute.

$$H. \times P. = \frac{P.L.A.N.}{33000} = \frac{P.L.\ diam.^2 \times N.}{42000}$$

$$P. = \frac{H.P.\ 33000}{L.A.N.} = \frac{H.P.\ 42000}{L.\ diam.^2 \times N.}$$

$$L. = \frac{H.P.\ 33000}{P.A.N.} = \frac{H\ P.\ 42000}{P.\ diam.^2 \times N.}$$

$$A. = \frac{H.P.\ 33000}{P.L.N.}$$

$$D. = \frac{\sqrt{H.P.\ 33000}}{P.L.N. \times .7854} = \frac{\sqrt{H.P.\ 42000}}{P.L.N.}$$

To find the horse power of a compound, triple, or quadruple expansion engine, calculate by the above rule the horse power of each cylinder separately, and then add the results. Treat each cylinder as if it were a separate engine.

EXAMPLE 1.—An engine having a cylinder 12" dia., 18" stroke, running at 300 revs. per minute, and the mean effective pressure is 45 lbs., what is the Horse Power?

EXAMPLE 2.—A triple expansion engine having cylinder ratios as 1 : 2.6 : 7 runs at 100 revs. The stroke is 4 ft., and the diameter of the high pressure cylinder is 18", and the mean effective pressure brought to a basis of the low pressure cylinder is 10 lbs., what is the H.P. of the engine and also the M.E.P. on the high and intermediate cylinder?

Strain on Cylinder Bolts.

DOES the admission of steam to a cylinder increase the stress on the cylinder bolts?

Is there any more stress on the bolts which secure the cylinder head when the cylinder is under pressure than when it is not?

Steam Consumption Per 1 H. P. Per Hour.

RULE.—The cubical contents of cylinder in feet × no. of strokes per hour × weight of one cubic foot of steam at point of cut off or where computation is made, and divide by the H. P.

EXAMPLE:—Engine stroke 18", dia. of cylinder 18", initial absolute pressure 100 lbs. cut off at 1/6 stroke, revs. 250 per minute, back pressure 16.3 lbs. absolute. Calculate M.E.P. the H.P. and the steam consumption per H.P. per hour.

Another method of finding water or steam consumption:— Take any point in the expansion curve of the diagram between cut off and release, calculate the volume in cubic inches to that point, multiply this volume by the pressure measured from vacuum, then divide by 14.7, multiply this quotient by the number of strokes in an hour and divide by 1728 which gives the cubic feet of water per hour, and this multiplied by 62.5 and divided by the H.P. of the engine, gives **pounds water per horse power per hour.**

Formula :—

Cub. ft. of steam per hour $\frac{V.P.}{25400}$

Pounds water per H.P. per hour. $\frac{V.P.N.}{H.P.\ 700{,}000}$

Where V. = Volume of cylinder in cubic inches to point of computation.

P. = Pressure measured from vacuum at point of computation.

N. = No. of strokes per hour.

H.P. = Horse power of engine.

Fuels and Combustion.

WHAT IS COAL? Geology has taught us that coal beds are the remains of previous vegetation and we may see the process of conversion progressing in every stage. We have the rank and unrestrained vegetation of the tropics; the peat bogs of Ireland and elsewhere, deposits of lignite, or unripe coal, cannel and other bituminous cools fully formed; and anthracite coals which are supposed to be of the earliest formation.

Nature of Fuels. The fuels used in the generation of steam are peat, wood, mineral oil, coal gas, lignite, coal and coke.

Peat lies midway between wood and coal. In its natural condition it contains 75 to 80% of its weight of water and when dried in air it contains 25 to 30%, which must be allowed for in estimating its heat value. According to analysis one pound of perfectly dry peat will give about 10260 heat units. In a test made between Reynoldsville screenings and patent peat fuel at the Metropolitan Street Railway, Toronto, the relative value of the fuels was as 100 : 92 or 100 pounds peat equal 92 pounds coal.

Wood when recently cut is of very little value as fuel owing to its large per centage of water. When air dried the quantity of water is seldom less than 20 to 25% and perfectly dry wood contains about half its weight hydrogen and oxygen in the proportions necessary for forming water during combustion. The calorific value of the same weight of various woods whether hard or soft is the same, and according to authorities one pound of wood is equal to 0.4 pound coal or two and a half pounds of wood are equivalent to one pound of coal.

Mineral oils contain a higher per centage of hydrogen than the other fuels, and although their use for steam generating purposes is not yet well established the results obtained are very promising, and there is no doubt that the use of this kind of fuel will become extensive, especially in oil districts.

Lignite occupies a position between peat and bituminous coal and is believed to be of later origin. It is inferior to the poorer qualities of bituminous coals.

Coal is by far the most important and in its ordinary state is more extensively used than any other fuel. Steam coals are divided into two main varieties known as bituminous and anthracite. **Bituminous** coal contains a high per centage of hydrogen and oxygen, and produces more or less smoke. **Anthracite** coals are composed almost wholly of carbon. **Cannel** coal is a variety of bituminous coal, very rich in carbon. It kindles readily and emits a bright flame like a candle. It is valuable as a gas coal but it is very little used for steam purposes. **Semi-bituminous** is softer than true anthracite and contains more volatile matter. When pure it is almost free from smoke. Anthracite coal ignites very slowly but burns at a high temperature. When burning there is no smoke given off.

Behaviour of Fuel in a Furnace.

THE fuel being in a solid state when thrown into the furnace, the first result of the heat to which it is exposed is to raise the temperature and to drive off the more volatile constituents in the form of gas. If these volatile gases are, raised to a sufficiently high temperature, and are brought into contact with sufficient oxygen, combustion ensues, and heat is liberated, but if the temperature is not sufficiently high and oxygen not present for combustion these gases pass away unconsumed, and instead of affording useful heat, actually carry away a quantity equal to their latent heat of gaseity. When those volatile gases are separated from the coal, the composition of the latter becomes almost identical with that of coke, the residue consisting of free carbon and ash. From this point combustion of every kind of coal proceeds in much the same manner.

Air required for combustion. As each pound of hydrogen combines for combustion with eight pounds of oxygen, and each pound of carbon with $2\frac{2}{3}$ pounds of oxygen, all of which has to be abstracted from air composed of one part by weight of oxygen to $3\frac{1}{3}$ parts nitrogen, it follows that for each pound of hydrogen consumed $1 + 3\frac{1}{2} \times 8 = 36$ pounds, and for each pound of carbon burnt $1 + 3\frac{1}{2} \times 2\frac{2}{3} = 12$ pounds of air must pass through the furnace, assuming the whole of its oxygen to enter into combustion. In practice this never holds good, and the actual quantity of air required to pass through the furnace will seldom be less than fifteen pounds to each one pound of carbonaceous fuel. In locomotives and other furnaces with strong draught the average quantity of air may be taken at eighteen pounds, and in furnaces with sluggish draught about twenty-fivepounds per pound of coal burned. A pound of air at average temperature and atmospheric pressure occupies thirteen cubic feet, and in the ordinary working conditions of the furnace 160 to 300 cubic feet of air will be required per pound of coal.

The heat available for the generation of steam depends upon the means taken to prevent the heat developed from being otherwise abstracted, and the only means whereby it can be dissipated are, by its radiation into the atmosphere from the furnace, and by the waste gases or products of combustion scaping into the chimney at a higher temperature than that at which they entered the furnace. Furnace radiation can be reduced to a very small amount, but the temperature of the gases can never fall below that of the steam they are heating.

Consequently, the heat utilized depends mainly upon the quantity of the waste gases and upon their temperature which they pass from contact with the boiler, which temperature should never exceed 600 degrees Fah., or about 550 degrees above that at which they were received into the furnace previous to combustion. For example, the heat derivable from a pound of good coal is 14,000 units, and if this coal be burnt with fifteen pounds of air and the products of combustion discharged up the chimney at a temperature of 600 degrees Fah., it is quite clear that the heat left in these sixteen pounds of waste gases is lost, so far as the generation of steam goes. The products of combustion will be composed of carbon di-oxide, oxygen and nitrogen in quantities of 3⅔ pounds, ⅔ pounds of coal and 11⅔ pounds respectively. Multiplying these weights by their specific heats we get 3.7 x .217=.8029, .7 x 2.18=1.526, and 11:7 x .244=1.2.855, and the sum of these results is 5.184 units, which is the quantity of heat necessary to raise the temperature of the whole weight of discharged gases one degree Fah. But these gases are discharged at 600 degrees Fah., or 550 degrees above their initial temperature, therefore 550 x 5.184=2850 units is the entire quantity carried off by the products of combustion, leaving 11,150 units for generating the steam. In the same way when twenty-five pounds of air pass through the furnace for each pound of coal burned there are twenty-six pounds of products of combustion discharged into the atmosphere at the same temperature, 600 degrees Fah., leaving 10,600 units for generation of steam.

With the Improved Jones Mechanical Stoker the air required per pound of coal is from 175 to 200 cubic feet, or an average of fourteen pounds of air, and the gases are discharged at from 340 to 375 degrees Fah., an average of 360, from which we get only 800 heat units carried off and wasted, leaving 13,200 units available for steam generation.

Comparing this with the above when twenty-five pounds of air are required, we have a difference in favor of the Underfeed Stoker of

$$100\left\{\frac{13,200-10,600}{10,600}\right\}=24\%$$

Wood as Fuel.

PERFECTLY dry wood contains about 50% of carbon, the remainder consisting almost entirely of oxygen and hydrogen in the proportions which form water. The proportion of ash is from one to five per cent. The total heat of combustion of all kinds of wood when dry, is almost exactly the same and is due to the 50% carbon. The following table gives the heating value of wood and the weights given are that of a cord :—

One cord	Hickory.....4,500	lbs.	=	1,800	lbs. coal
"	White Oak..3,850	"	=	1,540	"
"	Red Oak....3,260	"	=	1,304	"
"	Beech.......3,200	"	=	1,280	"
"	Hard Maple.2,900	"	=	1,160	"
"	Spruce......2,350	"	=	940	"
"	Poplar......2,350	"	=	940	"
"	Chestnut. ..2,350	"	=	940	"
"	Elm 2,350	"	=	940	"
"	Yellow Pine.2,000	"	=	800	"
"	White Pine..1,900	"	=	760	"

From the above it is seen that 100 pounds of wood equals forty pounds coal, and that hard wood has the same calorific value per pound as pine, assuming both to be dry.

A cord of wood 4 x 4 x 8=128 cubic feet. About 56% solid wood, the remainder interstitial spaces.

Coal Consumption in the Jones Stoker.

OVER 1,200 pounds of coal per hour can be burned with economy in one Jones Underfeed Stoker. This on a boiler where the grate surface was primarly 6x5 equals thirty square feet, gives us forty pounds coal per square foot of grate surface per hour, a result that cannot be obtained by ordinary hand-firing with good results where natural draft is used.

With hand-firing when the coal consumption goes above twenty pounds per square foot, there is a decrease in the evaporative performance by actual tests from 8.75 pounds from and at 212 to seven pounds when burning thirty-five pounds or 20%, whereas with the Stoker the results are almost identical, showing, without doubt, the enormous range that it can be put to. With a very light blast 100 to 150 pounds per hour can be burned with far better results than shaking grates or any other device.

Banking with the Stoker.

It is possible to shut a boiler down, say on Saturday at noon, with 100 pounds gauge pressure, and without touching the furnace, there will be fifty pounds pressure on the boiler on the following Wednesday, and the fire ready for starting up. Steam can be got up to the requisite pressure, 100 pounds, in less than five minutes. Is this possible with any other device? It is not.

Duty of an Engine.

THE DUTY OF AN ENGINE is the number of foot pounds of work done by the consumption of 100 pounds of coal. A new unit was recommended in 1891 by a committee of the A. S. M. E., viz., foot pounds of work per million heat units furnished by the boiler. This is equal to the old unit when the coal imparts 10,000 H. U. to the water in the boiler, or to an evaporation of 10.35 pounds, from and at 212 degrees per pound of coal. Taking the old unit, the duty of a pumping engine that will do 100,000,000 foot pounds for every 100 pounds coal burned is said to be 100 million.

EXAMPLE 1.—An engine requires four pounds coal per one H. P. What is the duty?

EXAMPLE 2.—The diameter of a pump plunger is twelve inches, and the length of stroke two feet, number of double strokes 10,000, coal burned 800 pounds, gauge pressure on main pipe shows sixty pounds, and the height of the gauge is twenty-four feet above the water in the well. Find the duty?

Factors of Evaporation.

TO facilitate calculations of boiler tests factors of evaporation are usually determined which show the ratio of heat in the steam at the observed boiler pressure to that of steam at atmospheric pressure. The formula for obtaining the factor is

$$\frac{H-h}{966}$$

where H is the total heat of steam at the observed pressure, h is the total heat of feed water, and the divisor 966 being the latent heat units in steam at atmospheric pressure.

The following table has been calculated by the above formula and its application is as follows: Example: In a certain boiler test, the evaporation per pound of coal was eight pounds from feed water at sixty-eight degrees, to steam 100 pounds gauge. What is the equivalent evaporation, supposing feed water was 212 degrees, and the steam was at atmospheric pressure?

Look down the column of temperatures until you come to 68, then look along the same line under column of pressures and under 100 pounds you will observe 1.1898, this multiplied by the actual evaporation will give the equivalent evaporation from and at 212 degrees, or 9.5 pounds.

To find the factors for intermediate pressures, say 55, 65, 75 pounds, etc., take the mean between 50 and 60, 60 and 70, etc. Steam at 95 pounds gauge, feed water at 80 degrees Fah., what is the factor? Take the sum of the factors of 90 and 100 pounds, divide by 2, or

$$\left\{\frac{1.752+1.1773}{2}\right\}=1.1762$$

The difference in the factor corresponding to a difference of one degree in temperature is .00104, therefore if the factor for any intermediate temperature can be easily obtained by subtracting from the higher or adding to the lower number this amount for every degree. Example: Feed water temperature 95 degrees, gauge pressure 100 pounds, what is the factor? The factor as given for 92 is 1.1649, and as 95 is three degrees above ∴ .00104 + 1.1649 = 1.1680.

Factors of Evaporation.

Temp. of Feed Water	Gauge Pressures.								
	50	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**
32	1.2144	1.2175	1.2202	1.2227	1.2249	1.2271	1.2290	1.2309	1.2326
38	1.2082	1.2112	1.2140	1.2164	1.2187	1.2208	1.2228	1.2247	1.2264
44	1.2051	1.2019	1.2078	1.2102	1.2125	1.2146	1.2166	1.2185	1.2202
50	1.1958	1.1988	1.2015	1.2040	1.2063	1.2084	1.2104	1.2123	1.2140
56	1.1896	1.1926	1.1953	1.1978	1.2001	1.2022	1.2042	1.2060	1.2078
62	1.1833	1.1864	1.1891	1.1916	1.1939	1.1960	1.1980	1.1998	1.2016
68	1.1771	1.1802	1.1829	1.1854	1.1877	1.1898	1.1917	1.1936	1.1954
74	1.1709	1.1708	1.1767	1.179[illegible]	1.1814	1.1835	1.1855	1.1874	1.1891
80	1.1647	1.1677	1.1704	1.1729	1.1752	1.1773	1.1793	1.1812	1.1829
86	1.1584	1.1615	1.1642	1.1667	1.1690	1.1711	1.1731	1.1749	1.1767
92	1.1522	1.1553	1.1580	1.1605	1.1628	1.1649	1.1668	1.1687	1.1705
98	1.1460	1.1490	1.1518	1.1542	1.1565	1.1586	1.1606	1.1625	1.1642
104	1.1398	1.1428	1.1455	1.1480	1.1503	1.1524	1.1544	1.1562	1.1580
110	1.1335	1.1366	1.1393	1.1418	1.1441	1.1462	1.1482	1.1500	1.1518
116	1.1273	1.1303	1.1331	1.1355	1.1378	1.1399	1.1419	1.1438	1.1455
122	1.1211	1.1241	1.1268	1.1293	1.1316	1.1337	1.1357	1.1375	1.1393
128	1.1148	1.1179	1.1206	1.1231	1.1253	1.1275	1.1294	1.1313	1.1331
134	1.1086	1.1116	1.1143	1.1168	1.1191	1.1212	1.1232	1.1251	1.1268
140	1.1023	1.1054	1.1081	1.1106	1.1129	1.1150	1.1170	1.1188	1.1206
146	1.0961	1.0991	1.1018	1.1043	1.1066	1.1087	1.1107	1.1126	1.1143
152	1.0898	1.0929	1.0956	1.0981	1.1004	1.1025	1.1044	1.1063	1.1081
158	1.0836	1.0866	1.0893	1.0918	1.0941	1.0962	1.0982	1.1000	1.1018
164	1.0773	1.0803	1.0831	1.0856	1.0878	1.0900	1.0919	1.0938	1.0955
170	1.0710	1.0741	1.0768	1.0793	1.0816	1.0837	1.0857	1.0875	1.0893
176	1.0648	1.0678	1.0705	1.0730	1.0753	1.0774	1.0794	1.0813	1.0830
182	1.0585	1.0615	1.0643	1.0668	1.0690	1.0712	1.0731	1.0750	1.0767
188	1.0522	1.0553	1.0580	1.0605	1.0628	1.0649	1.0669	1.0687	1.0705
194	1.0460	1.0490	1.0517	1.0542	1.0565	1.0586	1.0606	1.0624	1.0642
200	1.0397	1.0427	1.0454	1.0479	1.0502	1.0523	1.0543	1.0562	1.0579
206	1.0334	1.0364	1.0391	1.0416	1.0339	1.0460	1.0480	1.0499	1.0516
212	1.0271	1.0301	1.0329	1.0353	1.0376	1.0397	1.0417	1.0436	1.0453

From and at 212 Degrees.

To reduce boiler tests to a common standard of evaporation it is customary to consider the evaporation as taking place at atmospheric pressure, i.e. 212 degrees F., the temperature of the feed water being also considered as being at the same temperature, or in technical language the equivalent evaporation from and at 212 degrees. A pound of water at 212 degrees requires 966 heat units to evaporate it into steam, this is called the unit of evaporation.

The following formula is given for finding the equivalent evaporation of atmospheric pressure:—

$$W = \frac{W'(H - h)}{966}$$

Where W. = Equivalent evaporation from and at 212 degrees.
W'. = Observed or actual evaporation from temperature of feed.
H. = Total heat in steam.
h = Temperature of feed.

EXAMPLE.—In a boiler test the actual evaporation per pound coal is nine pounds. The temperature of the feed water is 180 degrees Fah. Gauge pressure 100 pounds. What is the equivalent evaporation from and at 212 degrees? Answer, 9.6 pounds.

The Limit of Speed.

THE speed of locomotives has not grown with their weight and size. There is a natural law which stands in the way of this. If we double the weight on the driving wheels the adhesion and consequent capacity for drawing loads is also doubled. Reasoning in an analogous way, it may be also said that if we double the circumference of the wheels the speed will be increased in like proportion. But if this be done it will require twice as much power to turn the large ones as was used for the small ones; and we then encounter the natural law that the resistance increases as the square of the speed, and probably even greater at very high velocities. At sixty miles an hour the resistance of the train is four times as great as it is at thirty miles. That is, the pull on the draw-bar must be four times as great in one case as the other. But at sixty miles this pull must be exerted for a given distance in half the time that it is at thirty miles, so that the power exerted and the amount of steam generated in a given period must be eight times as great in the one case as the other. This means that the capacity of the boiler, cylinders, etc., must be greater, with a corresponding addition to the weight of the machine. Obviously, if the weight per wheel is limited, we soon reach the size of the driving wheels, and other parts cannot be enlarged, which means that there is a certain proportion of wheels, cylinders and boiler, which gives us a maximum speed.

Steam.

SENSIBLE AND LATENT HEAT. Heat given to a substance, and warming it, is said to be **sensible** in the substance. Heat given to a substance and not warming it, is said to become **latent**.—(SIR WM. THOMPSON.)

Latent heat is the quantity of heat which must be communicated to unit mass of a body in a given state in order to convert it into another state without changing its temperature. —(MAXWELL.)

Latent heat of fusion. When a body passes from the solid to the liquid state, its temperature remains nearly stationary at a certain melting point during the operation of melting, and in order to make this operation go on, a quantity of heat must be transferred to the substance melted. The quantity is called the latent heat of fusion. In ice this is 144 units.

Latent heat of evaporation. When a body passes from the solid or liquid to the gaseous state, its temperature during the operation remains stationary at a certain boiling point, depending on the pressure of the vapor produced, and in order to make the evaporation go on a quantity of heat must be transferred to the substance evaporated. This heat does not raise the temperature, but disappears in causing it to assume

the gaseous state, and is called the latent heat of evaporation.

Total heat of evaporation, is the sum of the sensible and latent heats of evaporation. To raise one pound of water from freezing (32 degrees Fah.) point to the temperature of evaporation (212 degrees) takes 180 sensible heat units, and the additional heat required to evaporate it is called the latent heat; to evaporate one pound of water at 212 degrees into steam at the same temperature takes 966 heat units. The total heat of evaporation for water is therefore, 180 + 966 = 1146. If steam is generated at a higher temperature than 212 degrees Fah., the sensible heat increases and the latent heat decreases.

To find the latent heat of steam for any temperature the following formula will be found very nearly correct:—

$$\text{Latent heat} = 966 - .7\,(t - 212 \text{ degrees})$$

Where t = the temperature of evaporation.

From this we see that since the temperature of the steam is raised the latent heat diminishes only .7 of the increase in the sensible heat, it is therefore obvious that the total heat increases. For all temperatures above 212 degrees the latent heat is **less** than 966, for all temperatures below 212 degrees, the latent heat is **greater** than 966.

When the latent heat is found, at any temperature, the total heat of evaporation is easily determined.

$$\text{Total heat of steam} = \text{Sensible} + \text{latent heat.}$$
$$= (t - 32^\circ) + 966 - .7\,(t - 212)$$
$$= 1083 + .3\,t.$$

EXAMPLE.—What is the latent heat of steam at 90 pounds pressure, the temperature being 320° Fah., also what is the total heat of evaporation?

In 1847 Regnault made extensive tests for the French Government and found that

$$p = \left(\frac{t + 40}{147}\right)^5$$

Where p = absolute pressure in pounds per square inch.

t = temp. of boiling water in degrees Fah.

and from this we get

$$t = 147\sqrt[5]{p} - 40.$$

This is very nearly correct, for absolute pressures between 6 and 60 pounds, and above that add one to the result.

James Brownlee has given us an empirical formula, as follows:

$$\text{Log } p = 6.1993544 - \left(\frac{2938.16}{t + 371.85}\right)$$

$$\text{Approx.} = 6.2 - \frac{2940}{t + 372}$$

From which we get

$$t = \left\{\frac{2940}{6.2 - \log p}\right\} - 372$$

The following table, giving the pressures, log of pressure, and fifth roots, from 40 to 175 pounds will facilitate calculations for finding the temperature of steam from the steam pressure by the above methods.

Lbs. Press. Abso.	Log	5th Root	Lbs. Press. Abso.	Log	5th Root	Lbs. Press. Abso.	Log	5th Root
40	1.602	2.091	80	1.903	2.402	130	2.114	2.647
45	1.653	2.141	85	1.929	2.431	135	2.130	2.667
50	1.699	2.189	90	1.954	2.459	140	2.146	2.687
55	1.740	2.229	95	1.977	2.486	145	2.161	2.705
60	1.778	2.268	100	2.000	2.512	150	2.176	2.724
65	1.813	2.305	105	2.021	2.536	155	2.190	2.748
70	1.845	2.339	110	2.041	2.560	160	2.204	2.760
75	1.875	2.372	115	2.060	2.582	165	2.217	2.776
			120	2.079	2.605	170	2.230	2.783
			125	2.097	2.627	175	2.243	2.810

The following examples will illustrate the working of the formula.

First Method.—Steam pressure 100 pounds gauge. Find temperature 100 pounds gauge = 115 pounds absolute, fifth root = 2.583. Formula $t = 147\sqrt[5]{p} - 40$.

$$= 147 \times 2.582 - 40.$$

$$= 339^\circ \text{ Fah.}$$

Second Method.—

$$t = \left\{\frac{2940}{62 - \log p}\right\} - 372$$

$$= \frac{2940}{4.14} - 372$$

$$= 338^\circ \text{ Fah.}$$

Properties of Saturated Steam.

Absolute Press. in lbs. per sq. in.	Temperature Fah.	Total Heat above 32° Fah.		Latent Heat. Units	Wght. of 1 cub. ft. Steam in lbs.
		In the Water	In the Steam		
1	102.1	70.09	1113.1	1043.0	.00299
5	162.3	130.7	1131.4	1000.7	.01373
10	193.2	161.9	1140.9	979.0	.02641
14.7	212.0	180.9	1146.6	965.7	.03794
15	213.0	181.9	1146.9	965.0	.03868
20	227.9	197.0	1151.5	954.4	.05070
25	240.0	209.3	1155.1	945.8	.06253
30	250.2	219.7	1158.3	938.9	.07420
35	259 2	228.8	1161.0	932.2	.08576
40	267.1	263.9	1163.4	926.5	.09721
45	274.3	244.3	1165.6	921.3	.1086
50	280.9	251.0	1167.6	916.6	.1198
55	286.9	257.2	1169.4	912.3	.1311
60	292.5	262.9	1171.2	908.2	.1422
65	297.8	268.3	1172.8	904 5	.1533
70	302.7	273.4	1174.3	900.9	.1643
72	304.6	275.3	1174.8	899.5	.1687
74	306.5	277.2	1175.4	898.2	.1731
76	308.3	279.1	1176.0	896.9	.1775
78	310.1	280.9	1176.5	895.6	.1819
80	311.8	282.7	1177.0	894.3	.1862
82	313.5	284.5	1177.6	893.1	.1906
84	315.2	286.2	1178.1	891.9	.1950
86	316.8	287.9	1178.6	890.7	.1993
88	318.5	289.5	1179.1	889.5	.2036
90	320.0	291.2	1179.6	888.4	.2080
92	320.8	292.8	1180.0	887.2	.2123
94	323.1	294.4	1180.5	886.1	.2166
96	324.6	295.9	1181.0	885.0	.2210
98	326.1	297.4	1181.4	884.0	.2253

Absolute Press. in lbs. per sq. in.	Temperature Fah.	Total Heat above 32° Fah.		Latent Heat Units	Wght. of 1 cub. ft. Steam in lbs.
		In the Water	In the Steam		
100	327.6	298.9	1181.8	882.9	.2296
102	329.0	300.4	1182.3	881.9	.2317
104	330.4	301.9	1182.7	880.8	.2382
106	331.8	303.3	1183.1	879.8	.2425
108	333.2	304.7	1183.6	878.8	.2467
110	334.5	306.1	1184.0	877.9	.2510
112	335.9	307.5	1184.4	876.9	.2553
114	337.2	308.[illegible]	1184.8	875.9	.2596
116	338.5	31[illegible]	1185.2	875.0	.2638
118	339.7	31[illegible]	1185.6	874.1	.2681
120	341.0	312.8	1185.9	873.2	.2724
122	342.2	314.1	1186.3	872.3	.2766
124	343.5	315.3	1186.7	871.4	.2809
126	344.7	316.6	1187.1	870.5	.2851
128	345.9	317.8	1187.4	869.6	.2894
130	347.1	319.1	1187 8	868.7	.2936
132	348.2	220.3	1188.2	867.9	.2978
134	349.4	321.5	1188.5	867.0	.3021
136	350.5	322.6	1188.9	866.2	.3063
138	351.8	323.8	1189.2	865.4	.3105
140	352.8	325.0	1189.5	864.6	.3147
150	358.2	330.6	1191.2	860.6	.3358
160	363.3	335.9	1192.7	865.9	.3567
170	368.2	340.9	1194.2	853.3	.3775
180	372.8	345.8	1195.7	849.9	.3983
190	377.3	350.4	1197 0	846.6	.4191
200	381.6	354.9	1198.4	843.1	.4420
220	389.7	362.2	1200.8	838.6	.4852
240	397.3	370.0	1203.1	833.1	.5270
260	404.4	377.4	1205.3	827.8	.5686
280	411.0	384.3	1207.3	823.0	.6101
300	417.4	390.9	1209.2	818.3	.6515

Capacities and Horse Powers of Blowers.

For the Jones Underfeed Mechanical Stoker, Together with Coal Consumption per hour.

No	2 Oz. Pressure.				3 Oz. Pressure.			
	Revs. per Minute.	Cub. ft. Air Per Min.	Coal Consum- Per Hour in lbs.	H.P. Required.	Revs. Per Min.	Cub. ft. Air Per Min.	Coal Consum. Per Hour in lbs.	H.P. Required
7	2300	2000	700	1.5	2800	2400	900	3.25
9	1800	3000	1050	2.5	2200	3700	1375	5.
11	1475	4000	1400	3.	1800	5000	1800	6.5
13	1250	6000	2100	4.25	1550	7300	2700	8.75
15	1070	7000	2450	6.	1350	9400	3300	12.5
17	950	9000	3150	7.	1200	11000	4080	15.
19	850	12000	4200	10.	1050	15000	5600	21.
21	775	14000	4900	11.5	960	17000	6000	24.

NOTE.—The above horse powers are **net** at blower shaft, to this add engine friction.

For four ounce pressure, the power required is three times that of two ounce, and the cubic feet air per minute is 1.5 times that of two ounce.

How to operate the table. A boiler plant consisting of four boilers burns at the maximun 2400 pounds coal per hour. What size of blower would be necessary?

Look under two ounce blast in column "Coal Consumption per hour in pounds" until you come to the nearest number to 2400, and then see what size of blower that corresponds to,—in this case 15.

Pressure in Inches of Water.

And Corresponding Pressure in Ounces, with Velocities of Air due to Pressure.

Pressure per square inch in inches of water.	Corresponding pressure in ounces per square inch.	Velocity due to pressure in feet per minute.
.0625	.018	700
.125	.073	1400
.25	.145	1950
.375	.218	2410
.5	.290	2800
.625	.363	3100
.75	.436	3400
.875	.508	3700
1.	.581	3950
1.25	.726	4350
1.5	.872	4840
1.75	1.017	5220
2.	1.163	5600
2.5	1.453	6200
3.	1.744	6800
3.5	2.034	7300
4.	2.324	8000
4.5	2.615	8400
5.	2.906	9000
5.5	3.196	9400
6.	3.488	9700

Don't

Because you can't see through a thing, or understand it at once, don't condemn it; the trouble is with yourself.

Don't screw your workmen down to the lowest notch. Pay them good wages, you'll get better work and more of it. If you wish to curtail expenses commence in the boiler room by installing the Improved Jones Underfeed Mechanical Stokers. The effect will be probably your coal bill cut in two,

Horse Power Required for Different Speeds of Vessels.

THE power is usually taken as varying as the cube of the speed, but in different vessels and at different speeds it may vary from 2.8 power to the 3.5 power, depending upon the efficiency of the engines, propeller, etc., and the lines of the vessel. Taking ten knots as unity, the following table shows the relative powers for the different rates of increase.

Horse power ∝ / Speed in Knots Per Hour.	8	10	12	14	16	18	20	22	24	26
S2.8	.535	1.	1.666	2.565	3.729	5.185	6.964	9.095	11.60	15.24
S2.9	.524	1.	1.697	2.653	3.908	5.499	7.464	9.841	12.67	15.97
S3.	.512	1.	1.728	2.744	4.096	5.832	8.000	10.65	13.82	17.58
S3.1	.501	1.	1.700	2.838	4.293	6.185	8.574	10-52	15.09	19.34
S3.2	.490	1.	1.792	2.935	4.500	6.559	9.189	12.47	16.47	21.28
S3.3	.479	1.	1.825	3.036	4.716	6.957	9.849	13.59	17.98	23.41
S3.4	.468	1.	1.859	3.139	4.943	7.378	10.56	14.60	19.62	25.76
S3.5	.458	1.	1.893	3.247	5.181	7.824	11.31	15.79	21.42	28.34

The following examples will illustrate the working of the table:

A vessel of certain form and tonnage has a speed of ten knots an hour and the engine indicates 200 H. P. What will be the horse power if the vessel is sped up to fourteen knots per hour, the power varying as the cube of the speed?

On the line S3. under ten knots we get one, and under fourteen knots we get 2.744, showing that at fourteen knots the power is 2.744 times greater or

$$200 \times 2.744 = 549 \text{ H. P.}$$

In a certain vessel it was found that the coal consumption per day was fifty tons and the average speed twelve knots per hour, and the furnaces were afterwards equipped with the Improved Jones Underfeed Mechanical Stokers, and it was found that the daily consumption was fifty-five tons, and the average speed fourteen knots per hour. The power was observed to vary as 3.1 power of the speed. Find the saving effected by the installation of the Jones Stoker.

On the line S3.1 we get under twelve and fourteen knots, the horse powers are as 1.760 : 2.838 or 100 : 161. For fifty tons we get 100, and for fifty-five tons we get 161, showing that for the same coal consumption we get three H. P. indicated at the engine **after** the installation of the Stokers, as compared with two H. P. before, or a saving of 50%.

Horse Power Required for Vessels.

ANOTHER example will not be out of place to show how the rate of increase may be calculated.

A vessel makes twenty knots per hour and indicates 597 H. P., and at eighteen knots the one H. P. is 440. What will the H. P. be when the vessel is making twenty-two knots, the rate of increase of H. P. with increase of speed remaining constant.

Let x = rate of increase.

$18^x : 20^x :: 442 : 600.$

$x\,(\text{Log } 20 - \log 18) = \log 600 - \log 442.$

$x\,(0.30103 - 2.25527) = 2.77597 \div 2.64345.$

$x = 2.9.$

Showing that the H. P. $\propto S^x = 2.9.$

From the above table we get under twenty knots 7.464 which would give us at ten knots

$$\frac{597}{7.464} = 80 \text{ H.P.}$$

and we also find that at twenty-two knots the power is 9.841 times that at ten knots.

$\therefore 80 \times 9.841 = 788$ H. P. at 22 knots.

At 10 knots per hour		= 80	H. P.
18	" "	= 440	H. P.
20	" "	= 597	H. P.
22	" "	= 787	H. P.

The displacement of a vessel is the weight of the volume of water which it displaces. For sea water it is equal to the volume of the vessel beneath the water line in cubic feet, divided by 35, and for fresh water the divisor is 35.93. The displacement is measured in tons of 2240 pounds.

Don't think **you** know it all. There are others who perhaps know considerably more than **you** do, but have the good sense to hold their tongue.

The Horse Power of Steam Boilers.

THE horse power as applied to steam engines is equal to 33,000 feet pounds per minute, but in the case of boilers the term horse power is the evaporation of **thirty pounds water per hour at 100 Fah. into steam at seventy pounds,** gauge pressure. Some engines to-day would give nearly three indicated horse power for thirty pounds water consumption, others would take as high as forty pounds water per H.P. The number of heat units required to convert thirty pounds of water at 100° Fah. into steam at seventy pounds is 33,305, and is equivalent to 34½ pounds water evaporated from and at 212 degrees.

EXAMPLE 1.—What is the horse power of a boiler that evaporates at the rate of 2000 pounds of water per hour, temperature of feed fifty degrees, steam pressure 125 pounds gauge.

EXAMPLE 2.—How much water at 200 Fah. should be pumped into a boiler so that with gauge pressure of 150 pounds, the horse power developed would be 70.

EXAMPLE 3.—How much coal per horse power would be required if an evaporation of nine pounds from and at 212 degrees per pound coal is obtained at the boiler when the indicated horse power is 100, while the steam consumption is twenty-eight pounds per H. P. per hour.

Heating of Feed Water.

A DUE regard for economy in the production and saving of power requires that that contained in the heat of exhaust be applied to some useful purpose, and as a rule is best utilized in raising the temperature of the feed water to the highest point of which it is economically capable. To effect this the heater is used; and when in addition to this duty it is possible by its use to eliminate the impurities contained in the water, its great value to an economical steam plant will be acknowledged and appreciated.

That the feed water is a most important feature in a steam plant can be very easily proved by the following :—

Boiler pressure 60 pounds gauge, feed water 40 degrees before and 200 after it goes through the heater. What is the per centage gained by using the heater?

Temperature of steam at 60 pounds pressure.	307
Latent heat units in steam at 60 pounds......	899
Total heat units..............................	1206

The total heat supplied per pound of steam is 1206 - 40 if there were no feed water heater 1166 heat units; but heater increases the temperature from 40 to 200 degrees, or 160 degrees gain in heat.

$$\therefore \frac{160 \times 100}{1166} = 13.71\%$$

By increasing the temperature of the feed from 40 to 200 degrees there is a gain of 13.71%.

To find the percentage gain by heating feed water. RULE.—Divide 100 times the difference between the final and the initial feed temperatures by the total heat units in the steam, minus the initial temperature of the feed.

FORMULA.—

$$\left\{\frac{\text{Final temperature of feed} - \text{initial temperature of feed}}{\text{Total heat units in steam} - \text{initial temperature of feed}}\right\}$$

EXAMPLE 1.—Initial temperature of feed 45 degrees, final temperature 280 degrees, steam pressure 160 pounds gauge. Find % gain.

The following table shows the per cent. saving by heating feed water. Steam 60 lbs. gauge.

Initial Temp. of Feed.	FINAL TEMPERATURE OF FEED WATER.					
	120	140	160	180	200	250
35	7.25	8.96	10.66	12.09	14.09	18.34
40	6.85	8.57	10.28	12.00	13.71	17.99
45	6.45	8.17	9.90	11.61	13.34	17.64
50	6.05	7.71	9.50	11.23	13.00	17.28
55	5.64	7.37	9.06	10.85	13.60	16.93
60	5.23	6.97	8.72	10.46	12.20	16.58
65	4.82	6.56	8.32	10.07	11.82	16.20
70	4.40	6.15	7.91	9.68	11.43	15.83
75	3.98	5.74	7.50	8.28	11.04	15.46
80	3.55	5.32	7.09	8.87	10.65	15.08
85	3.12	4.90	6.63	8.46	10.25	14.70
90	2.68	4.47	6.26	8.06	9.85	14.32
95	2.24	4.04	5.84	7.65	9.44	13.94
100	1.80	3.61	5.42	7.23	9.03	13.55
110	.90	2.13	4.55	6.38	8.20	12.76
120	.00	1.84	3.67	5.52	7.36	11.95
130		.92	2.77	4.64	6.99	11.14
140			1.87	3.75	5.62	10.31
150			.94	2.83	4.72	9.46
160			.00	1.91	3.82	8.59
170				.96	2.89	7.71
180				.00	1.96	6.81
200					.00	4.85

EXAMPLE.—Initial temperature of feed is 55°, and the final temperature is 170. Find percentage gained if gauge pressure 60 pounds. ANSWER.—(See above table).

The Safety Valve.

THE CANADIAN STEAMBOAT ACT provides that every safety valve must have a lift equal to at least one quarter of its diameter, and that its area must equal one-half inch for every square foot of grate surface.

Rule of U.S. Supervision Inspectors of Steam Vessels as amended 1894. Lever safety valves to be attached to marine boilers shall have an area of not less than one square inch to two square feet of grate surface, and the seats of all such safety valves shall have an inclination of 45° to the centre line of their axes. Spring loaded safety valves shall be required to have an area of not less than one square inch to three square feet of grate surface, except as hereinafter otherwise provided for water tube, or coil, or sectional boilers, and each spring loaded valve shall be supplied with a lever that will raise the valve from its seat a distance of not less than that equal to one-eighth the diameter of the valve opening, and the seats of all such safety valves shall have an angle of inclination to the centre line of their axes of 45°. All spring loaded safety valves for water tube or coil, and sectional boilers required to carry a steam pressure exceeding 175 pounds per square inch, shall be required to have an area of not less than one square inch to six square feet of grate surface. Nothing herein shall be construed so as to prohibit the use of two safety valves on one water tube, or coil and sectional boiler, provided the combined area of such valves is equal to that required by rule for one such valve.

Rule in Philadelphia Ordinances. Bureau of Steam Engine and Boiler Inspection. Every boiler when fixed separately, and every set or series of boilers when placed over one fire, shall have attached thereto, without the interposition of any other valve, two or more safety valves, the aggregate area of which shall have such relations to the area of the grate, and the pressure within the boiler, as is expressed in the following Schedule A.

SCHEDULE A.—Least aggregate area of safety valve (being the least sectional area for the discharge of steam) to be placed upon all stationary boilers with natural or chimney draft.

$$\text{Area} = \left\{ \frac{22.5 \text{ area of grate in square feet}}{\text{Gauge pressure per square inch to be carried} + 8.62} \right\}$$

NOTE.—When boilers have a forced or artificial draft the area of the grate must be estimated at the rate of sixteen pounds of fuel burned per hour for every square foot of grate surface.

Let v = weight of valve in pounds.

P = Pressure of steam in pounds per square inch.

A = Area of valve in square inches.

d = Distance from fulcrum to centre of gravity of lever in inches.
L = Length of lever in inches.
l = Distance from fulcrum to centre of valve spindle.
W = Weight on lever in pounds.
Moment of W = W. L.
Moment of weight of lever = w. d.
Total downward moment = W.L. + w.d.
Upward moment = (Area of value × P – weight of valve) l.
= (A. P. – v) l.

For equilibrium we have

W. L. + w.d. = (A.P. – v) l.

From which we get the following formula :—

To find the weight.—

$$W. = \frac{l.\ A.\ P. - l.v. - w.d.}{L.}$$

$$= \frac{l\ (A.\ P. - v.) - w.d.}{L.}$$

To find the length of lever.—

$$L = \frac{l.\ (A.\ P. - v.) - w.d.}{W.}$$

To find the pressure.—

$$P = \frac{W.\ L. + w.d. + l.v.}{l.\ A.}$$

To find the distance from fulcrum to centre of valve.—

$$l = \frac{W.\ L. + w.d.}{A.\ P. - v.}$$

EXAMPLE.—Find the weight to be placed at the end of a uniform lever 20″ long, weighing 15 pounds, valve 3″ diameter, weight of valve and spindle 6 pounds, acting at 2″ from fulcrum. Steam press. 60 pounds.

Table of Logarithms.

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
1	0000	51	7075	101	0043	151	1789	201	3032	251	3996
2	3010	52	7160	102	0086	152	1818	202	3053	252	4014
3	4771	53	7242	103	0128	153	1847	203	[illegible]	253	4031
4	6020	54	7323	104	0170	154	1875	204	[illegible]	[illegible]	4048
5	6989	55	7403	105	0211	155	1903	20[illegible]	[illegible]	[illegible]	4065
6	7781	56	7481	106	0253	156	1931	20[illegible]	[illegible]	[illegible]	4082
7	8450	57	7558	107	0293	157	1858	207	[illegible]	[illegible]	4099
8	9030	58	7634	105	0334	158	1986	208	[illegible]	[illegible]	4116
9	9542	59	7708	109	0374	159	2014	209	3201	259	4133
10	0000	60	7781	110	0413	160	2041	210	3222	260	4149
11	0413	61	7853	111	0453	161	2068	211	3242	261	4166
12	0791	62	7923	112	0492	162	2095	212	3263	262	4183
13	1139	63	7993	113	0530	153	2121	213	3283	263	4199
14	1461	64	8061	114	0569	164	2148	214	3304	264	4216
15	1760	65	8129	115	0606	165	2174	215	3324	265	4232
16	2041	66	8195	116	0644	166	2201	216	3344	266	4248
17	2304	67	8260	117	0681	167	2227	217	3364	267	4265
18	2552	68	8325	118	0718	168	2253	218	3384	268	4281
19	2787	69	8388	119	0755	169	2278	219	3404	269	4297
20	3010	70	8450	120	0791	170	2304	220	3424	270	4313
21	3222	71	8512	121	0827	171	2329	221	3443	271	4329
22	3424	72	8573	122	0863	172	2355	222	3463	272	4345
23	3617	73	8633	123	0899	173	2380	223	3483	273	4361
24	3802	74	8692	124	0934	174	2405	224	3502	274	4377
25	3979	75	8750	125	0969	175	2430	225	3521	275	4393
26	4149	76	8808	126	1003	176	2455	226	3541	276	4409
27	4313	77	8864	127	1038	177	2479	227	3560	277	4424
28	4471	78	8920	128	1072	178	2504	228	3579	278	4440
29	4623	79	8976	129	1105	179	2528	229	3598	279	4456
30	4771	80	9030	130	1139	180	2552	230	3617	280	4471
31	3913	81	9084	131	1172	181	2576	231	3636	281	4487
32	5051	82	9138	132	1205	182	2600	232	3654	282	4502
33	5185	83	9190	133	1238	183	2624	233	3673	283	4517
34	5314	84	9242	134	1271	184	2648	234	3692	284	4533
35	5440	85	9294	135	1303	185	2671	235	3710	285	4548

No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.	No.	Log.
36	5563	86	9344	136	1335	186	2695	236	3729	286	4563
37	5682	87	9395	137	1367	187	2718	237	3747	287	4578
38	5797	88	9444	138	1398	188	2741	238	3765	288	4593
39	5910	89	9493	139	1430	189	2746	239	3783	289	4608
40	6020	90	9542	140	1461	190	2787	240	3802	290	4623
41	6127	91	9590	141	1492	191	2810	241	3820	291	4638
42	6232	92	9637	142	1522	192	2833	242	3838	292	4653
43	6334	93	9684	143	1553	193	2855	243	3856	293	4668
44	6434	94	9731	144	1583	194	2878	244	3873	294	4683
45	6532	95	9777	145	1613	195	2900	245	3891	295	4698
46	6627	96	9822	146	1643	196	2922	246	3909	296	4712
47	6720	97	9867	147	1673	197	2944	247	3927	297	4727
48	6812	98	9912	148	1702	198	2961	248	3944	298	4742
49	6902	99	9956	149	1731	199	2988	249	3962	299	4756
50	6989	100	0000	150	1760	200	3010	250	3979	300	4771

To multiply by logarithms, add the logarithms together and find the corresponding number.

To divide by logarithms, subtract one from the other and find the corresponding number.

To extract the root, divide the logarithms by the index of the root and find the corresponding number.

To raise a number to any power, multiply the logarithms by the index of the power and find corresponding number.

To Cut the Strongest Beam from a Log.

Divide the diameter, a d, into three equal parts, ab, bc, cd. From c draw the line bc at right angles to ad, and from c draw cf, also at right angles, but to the opposite side from c.f. Join ac, cd, df, af, then acfd is the cross section of the strongest beam. FORMULA.—Depth^2 × breadth = maximum.

To cut the stiffest beam divide the diameter into four instead of three parts, and proceed as above. FORMULA.—Depth^3 × breadth = maximum.

Cost of the Jones Stoker.

OWING to the fact that the conditions vary in each plant it is impossible for us to issue a price list.

By sending us, in writing, the following data we will send you our figure for equipping your boilers, together with our guaranteed saving.

Our figure includes the complete installing of the Stokers, unless otherwise specified.

Data Required for Tender.

Number of boilers.......... Type or types of boilers......

Dimension of boilers.......... Horse power (builder's)......

Size of grate surface........ length..... .width.

Maximum quantity of coal burned per hour.......... pounds.

(This amount should be carefully determined).

Forced or natural draft..............

(If forced, give size of blower and maker's name).

Style of front............. Give sketch with dimensions of doors and position of same.................

What is the nature of the floor?............

Is it necessary to have separate engine to run blower?......

If so, give location of same....... ....

Kind of fuel used............ Cost of same............

Amount used daily............. Give number of hours run per day..............

Can a cheaper grade of coal be obtained?... What price?...

Rough sketches, showing the position of the boilers, together with the proposed location of blower and engine.

It pays to put in the Jones Stoker if you are only burning 150 pounds coal per hour.

Shafting, Belting, Pulleys & Gears.

SHAFTING.—The following rule for determining size of shaft for transmitting a given power at a given speed, when the hangers are 8' between centres will be found useful.

$$\text{Diameter in inches} = \sqrt{\frac{H.P. \times 80}{R.P.M.}}$$

BELTS.—The length of belts may be found as follows:

$$\frac{(D+d+3.16)}{2}+2D'=\text{length}$$

Where D = diameter of large pulley.
d = diameter of small pulley.
D′ = distance between centres.

PULLEYS AND GEARS.—Rules for determining the size and speed of pulleys and gears.

$$\text{Diam. of driver}=\frac{\text{Driven}\times\text{r. p. m. of driven}}{\text{r. p. m. of driver}}$$

$$\text{Diam. of driven}=\frac{\text{Driver}\times\text{r. p. m. of driver}}{\text{r. p. m. of driven}}$$

$$\text{r. p. m. of driver}=\frac{\text{Driven}\times\text{r. p. m. of driven}}{\text{diam. of driver}}$$

$$\text{r. p. m. of driven}=\frac{\text{Driver}\times\text{r. p. m. of driver}}{\text{diam. of driven.}}$$

Where r. p. m. = revs. per minute.

Rules for Conducting Boiler Tests.

The following rules were recommended by the committee of the A.S.M.E. on boiler tests.

Preliminaries to a Test.

I.—In preparing for and conducting trials of steam boilers the specific object of the proposed trial should be clearly defined and steadily kept in view.

II.—Measure and record the dimensions, position, etc., of grate and heating surfaces, flues and chimneys, proportion of air-space in the grate surface, kind of draft, natural or forced.

III.—Put the boiler in good condition. Have heating surfaces clean inside and out, grate bars and sides of furnace free from clinkers, dust and ashes removed from back connections, leaks in masonry stopped, and all obstructions to draft removed. See that the damper will open to the full extent, and that it may be closed when desired. Test for leaks in masonry by firing a little smoky fuel and immediately closing the damper. The smoke will then escape through the leaks.

IV.—Have an understanding with the parties in whose interest the test is to be made as to the character of the coal to be used. The coal must be dry, or if wet, a sample must be dried carefully and a determination of the amount of moisture in the coal made, and the calculations of the results of the test corrected accordingly.

V.—In all important tests a sample should be selected for chemical analysis.

VI.—Establish the correctness of all apparatus used in the test for weighing and measuring. These are:—1, Scales for weighing coal ashes, and water; 2, Tanks or water meters for measuring water. Water meters as a rule should only be used as a check on other measurements. For accurate work, the water should be weighed and measured in a tank. 3, Thermometers for taking the temperatures of air, steam, feed-water, waste gases, etc.; 4, Pressure guages, draught guages, etc.

VII.—Before beginning a test the boiler and chimney should be thoroughly heated to their usual working temperature; if the boiler is new, it should be in continuous use at least a week before testing so as to dry the mortar thoroughly and heat the walls.

VIII.—Before beginning a test the boiler and connections should be free from leaks, and all water connections including blow and extra feed pipes should be disconnected or stopped with blank flanges, except the particular pipe through which water is to be fed to the boiler during the trial. The blow-off pipe should remain exposed.

Starting and Stopping a Test.

IX.—A test should last 10 hours of continuous running, and twenty-four hours whenever practicable. The conditions of the boiler and furnace in all respects should be, as nearly as possible, the same at the end as at the beginning of the test. The steam pressure should be the same, the water level the same, the fire upon the grates should be the same in quantity and condition, and the walls, flues, etc., should be of the same temperature. To secure as near an approximation to exact uniformity as possible in conditions of the air and in temperature of the walls and flues the following method of starting and stopping a test should be adopted :—

X. STANDARD METHOD.—Steam being raised to the working pressure, remove rapidly all the fire from the grate, close damper, clean the ash pit, and as quickly as possible start a new fire with weighed wood and coal, noting the time of starting the test and the height of water level while the water is in a quiescent state, just before lighting the fire. At the end of the test remove the whole fire, clean the grates and ash pit, and note the water level when the water is in a quiescent state; record the time of hauling the fire at the end of the test. The water level should be the same as at the beginning of the test. If it is not the same a correction should be made by computation and not by operating the pump after test is completed.

XI.—ALTERNATE METHOD.—Instead of the Standard Method above described the following may be employed where local conditions render it necessary :

At the regular time for slicing and cleaning fires, have them burned rather low, as is usual before cleaning, and then thoroughly cleaned ; note the amount of coal left in the grate as nearly as can be estimated ; note the pressure of steam and the height of the water level, which should be at the medium height to be carried throughout the test at the same time, and note this time as the time of starting the test. Fresh coal which has been weighed should now be fired. The ash pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave the same amount of fire, and in the same condition on the grates as at the start. The water level and steam pressure should be brought to the same point as at the start, and the time of the end of the test should be noted just before fresh coal is fired.

During the Test.

XII.—KEEPING THE CONDITIONS UNIFORM.—The boiler should be run continuously without stopping for meal times or for rise or fall of pressure of steam due to change of demand for steam. The draught being adjusted to the rate of evaporation or combustion desired before the test is begun, it should be retained constant during the test by means of the damper.

If the boiler is connected to a main steam pipe with other boilers, the safety valve on the boiler being tested should be set a few pounds higher than those of the other boilers, so that in case of a rise in pressure the other boilers may blow off, and the pressure be reduced by closing their dampers, allowing the damper of the boiler being tested to remain open and firing as usual.

All the conditions should be kept as nearly uniform as possible, such as force of draught, pressure of steam, and height of water. The time of cleaning the fires will depend on the character of the fuel, the rapidity of combustion, and the kind of grates. When very good coal is used and the combustion not too rapid, a ten hour test may be run without any cleaning of the grates, other than just before the beginning and just before the end of the test.

XIII.—Keeping the Records.—The coal should be weighed and delivered to the firemen in equal portions, each sufficient for about one hour's run, and a fresh portion should not be delivered until the previous one has all been fired. The time required to consume each portion should be noted, the time being recorded at the instant of firing the first of each even portion.

XIV.—Priming Tests.—In all tests in which accuracy of results is important, calorimeter tests should be made of the per centage of moisture in the steam, or of the degree of super-heating. At least ten such tests should be made during the trial of the boiler, or as many as to reduce the probable average error to less than one per cent., and the final records of the boiler test corrected according to the average results of the calorimeter tests. On account of the difficulty of securing accuracy in these tests, the greatest care should be taken in the measurements of weights and temperatures. The thermometer should be accurate within a tenth of a degree, and the scales on which the water is weighed to within one hundredth of a pound.

Analysis of Gases, Measurement of Air Supply, etc.

XV.—In tests for purposes of scientific research, in which the determination of all the variables entering into the test is desired, certain observations should be made which are in general not necessary in tests for commercial purposes. These are the measurement of the air supply, the determination of its contained moisture, the measurement and analysis of the flue gases, the determination of the amount of heat lost by radiation, of the amount of infiltration of air through the setting, the direct determination by calorimeter experiments of the absolute heating value of the fuel, and by condensation of all the steam made by the boiler, of the total heat imparted to the water.

The analysis of the flue gases is an especially valuable method of determining the relative value of different methods of firing, or of different kinds of furnaces. In making these analyses great care should be taken to procure average samples, since the composition is apt to vary at different points of the flue and the analyses should be entrusted only to a thoroughly competent chemist who is provided with complete and accurate apparatus.

As the determination of the other variable mentioned above are not likely to be undertaken except by engineers of high scientific attainments, it is not deemed advisable to include in this code any specific directions for making them.

Record of Test.

XVII.—A log of the test should be kept on properly prepared blanks containing headings as follows :—

Time	Pressures			Temperatures					Fuel		Feed Water	
	Barometer	Steam Guage	Draught Guage	External Air	Boiler Room	Flue	Feed Water	Steam	Time	Lbs.	Time	Lbs. or Cubic Feet.

Reporting the Trial.

XVII.—The final results should be recorded upon a properly prepared blank, and should include as many of the following items as are adapted for the specific object for which the trial is made. The items marked with a * may be omitted for ordinary trials, but are desirable for comparison with similar data from other sources.

Results of the trials of a ....
Boiler at ....
To determine ....

---

1. Date of trial		....
2. Duration of trial	hours	....
DIMENSIONS AND PROPORTIONS.		
(Leave space for complete description)		
3. Grate surface . . wide . . long . . . area	sq. feet	....
4. Water heating surface	sq. feet	....
5. Superheating surface	sq. feet	....
6. Ratio of water heating surface to grate surface	sq. feet	....
AVERAGE PRESSURES.		
7. Steam pressure in boiler by gauge	pounds	....
*8. Absolute steam pressure	pounds	....
*9. Atmospheric pressure, per barometer	in.	....
10. Force of draught in inches of water	in.	....
AVERAGE TEMPERATURES.		
*11. Of external air	deg.	....
*12. Of fire room	deg.	....
*13. Of steam	deg.	....
14. Of escaping gases	deg.	....
15. Of feed water	deg.	....
FUEL.		
16. Total amount of coal consumed	pounds	....
17. Moisture in coal	per cent.	....
18. Dry coal consumed	pounds	....
19. Total refuse dry .... pounds	per cent.	....
20. Total combustible (18 – 19)	pounds	....
*21. Dry coal consumed per hour	pounds	....
*22 Combustible consumed per hour	pounds	....

RESULTS OF CALORIMETRIC TESTS.

23. Quality of steam, dry steam taken as unity ..	....
24. Per centage of moisture in steam	....
25. Number of degrees superheater	....

WATER.

26. Total weight of water pumped into boiler and apparently evaporated .... pounds	....
27. Water actually evaporated, corrected per quality of steam .... pounds	....
28. Equivalent water evaporated into dry steam from and at 212 degrees F............ pounds	....
*29. Equivalent total heat derived from fuel in B. T.U. .... B.T.U.	....
30. Equivalent water evaporated into dry steam from and at 212 degrees F. per hour... pounds	....
31. Water actually evaporated per lb. of dry coal from actual pressure and temperature.. pounds	....
32. Equivalent water evaporated per pound of dry coal from and at 212 degrees F........ pounds	....
33. Equivalent water evaporated per pound combustible, from and at 212 degrees F.... pounds	....
*34. Equivalent water evaporated per lb. of dry coal at 70 lbs. gauge pressure from 100 degrees F.................................. pounds	....
35. Dry coal actually burned per sq. ft. of grate surface per hour .... pounds	....
36. Water evaporated from and at 212 degrees F. per sq. ft. of heating surface per hour.. pounds	....
37. Water evaporated per hour from temperature of 100 degrees F. into steam of 70 lbs. gauge pressure.... — per sq. ft. of grate surface.. pounds	....
— per sq. ft. of water heating surface. .... pounds	....
— per sq. ft. of least area for draft .... pounds	....

COMMERCIAL HORSE POWER.

38 On basis of thirty lbs. of water per hour evaporated from temperature of 100 degrees F. into steam of 70 pounds gauge pressure..... H.P.	....
39. Horse power, builder's rating, at....... sq. ft. per horse power .... H.P.	....
40. Per cent. developed above, and below rating .	....

, TORONTO, ONT.

...st No. 6		Test No. 7		Aggregate	
...s.	*Hand*	*Jones*	*Hand*	*Jones*	*Hand*
3	Sep. 3	Sep. 6-7	Sep. 6-7	Aug. 25–Sep. 7	Aug. 25–Sep. 7
1¼	11¼	24	24	94.2	93.75
200	10200	16000	15800	74447	81770
589	75190	130912	112106	621080	593945
	158	160	160	156.2	155.5
	145	146	146	144.7	143.5
	1328	1214	1868	6158	8998
189	7.371	8.182	7.095	8.342	7.262

COMPETITIVE

MADE AT

THE TERAULEY ST. STATION OF THE TORONTO ELEC

Points Observed	Test No. 1		Test No. 2		Test No. 3		Test No. 4	
	Jones	*Hand*	*Jones*	*Hand*	*Jones*	*Hand*	*Jones*	*Hand*
Date of Test	Aug. 25	Aug. 25	Aug. 26	Aug. 26	Aug. 27	Aug. 27	Aug. 30	Aug. 30
Duration of Test in hours	12	12	[illegible]	13	12⅙	12¾	10¾	10¾
Total coal including wood equivalent	8400	10400	10447	[illegible]	7800	9436	8400	9600
Total water evaporated at temp. of feed	72787	80206	84116	78484	65649	68160	70886	71990
Average pressure	152	152	153	153	152	152	156	156
Average feed temp. Fah	143	143	148	148	147	147	143	143
Total ash	570	915	997	1504	771	932	738	925
Actual evap. per lb. coal at temp. of feed	8.665	7.712	8.051	6.924	8.416	7.329	8.439	7.499

ETITIVE TESTS

MADE AT

THE TORONTO ELECTRIC LIGHT CO., TORONTO, ONT.

T No. 3		Test No. 4		Test No. 5		Test No. 6		Test No. 7		Aggregate	
	Hand	*Jones*	*Hand*	*Jones*	*Hand*	*Jones*	*Hand*	*Jones*	*Hand*	*Jones*	*Hand*
7	Aug. 27	Aug. 30	Aug. 30	Sep. 1-2	Sep. 1-2	Sep. 3	Sep. 3	Sep. 6-7	Sep. 6-7	Aug. 25–Sep. 7	Aug. 25–Sep. 7
⅙	12¾	10¾	10¾	24	24	11¼	11¼	24	24	94.2	93.75
00	9436	8400	9600	13200	15000	10200	10200	16000	15800	74447	81770
49	68160	70886	71990	110141	107609	86589	75190	130912	112106	621080	593945
	152	156	156	158	158	158	158	160	160	156.2	155.5
	147	143	143	141	141	145	145	146	146	144.7	143.5
	932	738	925	1089	1526	[illegible]79	1328	1214	1868	6158	8998
16	7.329	8.439	7.499	8.345	7.[illegible]	8.489	7.371	8.182	7.095	8.342	7.262

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Pressure of Air.

UNTIL near the middle of the 17th century it was not even suspected that air possessed either weight or elastic force. Pumps being an earlier invention had come into general use for raising water, and practical men had noted the fact that water rose above the natural level in the pump tube when the valve or bucket had withdrawn the air from that part of the tube. A pump was erected at Florence for the Duke of Tuscany, and it failed to raise any water, and its failure was a very unexpected result. It was then ascertained that the water was 33 feet from the pump valve and only rose to about that height, but not within the action of the pump, hence the cause of the failure was apparent, but not so the limit thus assigned to Nature's abhorrence of a vacuum. Galileo was consulted, but was unable to give any valid reason for this limit at the time, but on reflection concluded that the air had weight and that the weight pressing on the water caused it to rise. Following out this reason, Torricelli, his pupil, constructed the first barometer, and to determine by experiment the relative weight and pressure of air, Torricelli took a tube about 36" long, closed at one end and filled it with mercury, and putting his fingers to the open end inserted the tube with its open end in a cup containing both water and mercury. He then withdrew his finger while the end was immersed in the mercury, when it flowed out until it became stationary at a height of [redacted] about 30 inches. When the end of the tube was raised out of the mercury and open to the water the mercury flowed out, and the water rushed into the top of the tube, showing that it would have risen higher had the tube been longer.

The specific weight of mercury is 13.6 times heavier than water, hence the weight of a column of water equal in weight to the weight of a column of mercury 30" high would be $30 \times 13.6 \div 12 = 34$ feet, which water would rise in a perfect vacuum by the pressure of air on its surface.

Since a cubic foot of water is equal to 1000 ounces, a cubic foot of mercury would be equal to 13,600 ounces, and one inch of mercury would be equal to $13{,}600 \div 1728 = 7.87$ ounces, therefore $30 \times 7.87 \div 16 = 14.75$ pounds would be the elastic force of the air at the sea level.

Measures of Pressures and Weights.

1 pound per sq. inch =	144 pounds per square foot. 2.0355 inches of mercury at 32° Fah. 2.0416 inches of mercury at 62° Fah. 27.71 inches of water at 62° Fah.
1 Atmosphere....... =	14.7 pounds per square inch. 29.92 inches of mercury at 32° Fah. 30 inches of mercury at 62° Fah. 33.947 feet of water at 62° Fah.
1 foot of water at 62° Fah........ =	4.33 pounds per square inch. 62.355 pounds per square foot. 883 inches of mercury at 62° Fah.
1 inch of mercury at 62° Fah..... =	49 pounds per square inch. 70.56 pounds per square foot. 1.132 feet of water at 62° Fah. 13.58 inches of water at 62° Fah.

Weight of one Cubic Foot of Pure Water.

At 32° Fah. (freezing point) 62.418 pounds.

39.1° Fah. (max. density) 62.425 pounds.

62° Fah., standard temperature, 62.355 pounds.

212° Fah., boiling point, under atmosphere, 59.76 pounds.

American gallon = 231 cubic inches of water at 62° Fah. = 8.3356 pounds.

British gallon = 277.274 cubic inches of water at 62° Fah. = 10 pounds.

The following formula is given by Rankin for finding the weight of water per cubic foot at any temperature:—

Let W = Required weight or density.

T = Temperature of the water of which the weight is required.

Max. density = 62.425 pounds.

FORMULA =

$$\frac{2.\ \text{max. density.}}{\dfrac{T+461}{461+39.1} + \dfrac{461+39.1}{T+461}}$$

$$= \frac{124.85}{\dfrac{T+461}{500} + \dfrac{500}{T+461}}$$

EXAMPLE.—What is the weight of a cubic foot of water at 175° Fah.? Answer, 60.66.

Weight of Water per Cubic Foot.

From 32° to 500° F.

Temp. Fah.	Wght. cub ft. in lbs.	Temp Fah.	Wght. cub. ft. in lbs.	Temp. Fah.	Wght. cub. ft. in lbs.	Temp. Fah.	Wght. cub. ft. in lbs.
32	62.42	115	61.82	200	60.07	350	55.52
35	62.42	120	61.74	205	59.95	360	55.16
40	62.42	125	61.65	21[illegible]	59.82	370	54.79
45	62.42	130	61.56	212	59.76	380	54.41
50	62.41	135	61.47	220	59.64	390	54.03
55	62.39	140	61.37	230	59.37	400	53.64
60	62.37	145	61.28	240	59.10	410	53.26
65	62.34	150	61.18	250	58.81	420	52.86
70	62.31	155	61.08	260	58.52	430	52.47
75	62.28	1[illegible]	60.98	270	58.21	440	52.07
80	62.23	165	60.87	280	57.90	450	51.66
85	62.18	170	60.77	2[illegible]	57.59	460	51.26
[illegible]	62.13	175	60.66	300	57.26	470	50.85
9[illegible]	62.08	180	60.55	310	56.93	480	50.44
1[illegible]	[illegible]2.02	185	60.44	320	56.58	490	50.03
105	[illegible]1.96	190	60.32	330	56.24	500	49.03
110	61.89	195	60.20	340	55.88		

Heating by Electricity. (Milne)

THE heat produced in a conductor is directly proportioned (1) to the square of the current; (2) to the resistance of the conductor; and (3) to the time the current is flowing, or

J. H. = C² R. t.

where J = Joule's Mechanical Equivalent.

H = No. of heat units.

C = Current in amperes.

R = Resistance of conductor.

t = time current is flowing in seconds.

As 1 H. P. = 33000 foot pounds per minute = 550 foot pounds per second = 746 watts and one British heat unit = 772 foot pounds, therefore 1 degree Fah. $= \frac{772}{550} = 1.403$ H. P. or 1047.3 watts. This will represent the value of J when dealing with B. H. units.

$$H = \frac{C.^2 R. t.}{1047} = \frac{C. E. t.}{1047} = \frac{E.^2 t.}{1047}$$

Where E = E. M. F.

In the best of lighting and power plants it takes a consumption of 2½ pounds coal per indicated horse power per hour; and allowing 90% efficiency in the engine, 93% in the generator and 90% in the circuits, we get say 75% combined efficiency, or for every horse power generated at the engine we would get ¾ H. P. at the heater on the consumer's premises, which is equivalent to 3.3 pounds coal per E. H. P. In many electrical plants where poor engines and poor generators are employed, together with a lack of copper, this amount of coal would be more than doubled.

For a coal consumption of 2½ pounds we get

$$H = \frac{C.^2 R. t.}{J} = 1926 \text{ or } 770 \text{ H. U. per pound of coal.}$$

In good hot water or steam heating systems an average of 9500 heat units are utilized per pound coal. The relative economies would therefore be 770 : 9500, or 1 : 12.5; that is to say it would cost 12½ times more to heat by electricity than by steam. In plants where the coal consumption averages say 4 pounds we have the relative economies 1 : 20. Where small quantities of heat are required, and only momentarily, the electric heater is more economical than anything else, but we may never expect electric heating to take the place of hot water or steam heating, where coal has to be used for the generation of steam to drive the engines, and it is questionable even where there is plenty of water power whether companies would load up their generators and mains with a "heating load" for such a small revenue for the power delivered.

Summary.

The Improved Jones Underfeed Mechanical Stoker and Smokeless Furnace

1. Can be attached to any kind of boiler, land or marine.
2. Will burn from 100 to 1200 pounds coal hourly with greatest economy.
3. Will increase evaporation 15 to 30% over best hand firing.
4. Will increase boiler capacity from 35 to 75% above maker's rating.
5. Will be practically smokeless under ALL ordinary working conditions.
6. Will reduce fuel bills from 15 to 50%.
7. Will reduce repairs on boilers, there being no opening of doors, consequently no chilling of plates.
8. Will take all the heat out of the coal.
9. Will cost less for repairs than any other stoker or furnace.
10. Will do more work with less trouble than any other stoker or furnace.
11. Will pay for itself in a year in many cases.
12. Will pay YOU, yes you, to investigate its merits.
13. Will reduce the volume of heated gases passing up the chimney.
14. Will decrease the velocity of the gases passing over the heating surfaces and
15. Will therefore reduce the temperature of the escaping gases to a few degrees above the temperature of the steam
16. Will fulfil the guarantee or no sale.
17. Will give better comparative results than economizers installed in similar plants.
18. Will give as good results in many cases from screenings without smoke as that obtained from best lump coal hand fired.
19. It is the only Stoker built on correct scientific principles and
20. Is a labor saver, not a man killer like other devices you are acquainted with.
21. It is the only successful Stoker in the market.

22. It is installed in the principal steam plants in Canada.

23. Its successful working does not depend on the skill of the operator.

24. No ash, no dirty tubes, owing to absence of smoke, no grate bars to clinker up or burn out, no ash pits to clean out; no banking required. No trouble.

25. No superior. No equal.

Examination Questions
For Engineers.

The following easy questions should be tried by all engineers :—

1. In a Newcomens engine the diameter of the cylinder is 40 inches, stroke 6 feet, pressure per square inch due to vacuum 11 pounds, 20 double strokes per minute. Neglecting friction, how many pounds of water would it lift per minute to a height of 125 feet ?

2. Distinguish between heat and temperature. How many units of heat are required for raising 1 pound of water from 32 to 212 degrees Fah., and then evaporating it into steam. How much mechanical work would be done in each operation.

3. Define the "lap" and "lead" of a slide valve, and state the purpose for which each is employed.

4. A safety valve 3 inches diameter is held down by a lever and weight. The lever is 40 inches long and the valve centre is 4 inches from the fulcrum ; the weight is 56 pounds. Omitting the weight of the lever and valves from the calculation, at what pressure would the valve be lifted ?

5. Assuming steam expands in a cylinder according to Boyle's law, show how to find the terminal pressure for a given boiler pressure and cut off, and how to find the mean pressure during the stroke, then assuming that the boiler pressure is

100 pounds absolute per square inch, and cut off takes place at ¼ stroke, determine the terminal pressure and also the mean pressure for the whole stroke.

6. What is meant by "clearance" and "cushioning." What effect has clearance on the diagram?

7. Cylinder of an engine 20 inches diameter, crank 12 inches long, connecting rod 4 feet long, steam pressure 60 pounds. Find the turning effort on the crank-shaft when the crank is at right angles to connecting rod?

8. Taking steam at 60 pounds absolute, sketch 3 diagrams showing the amounts of work obtained from a given weight of steam?

(1) When used in an engine without expansion or condensation.

(2) When steam is cut off at half stroke, but not condensed.

(3) When steam is cut off at half stroke, but condensed.

9. What is the latent heat of steam at 212 degrees expressed in foot pounds, if one pound of steam at 212 degrees is mixed with 10 pounds water at 60 degrees Fah. Find the resulting temperature?

10. Why are the longitudinal joints in cylindrical boilers usually double rivetted, while the tranverse joints are only single rivetted. Prove your statement by calculation.

11. What is the object of a separate expansion valve and where is it placed? If a gridiron expansion valve has a travel of 1 inch and the ports 12 inches wide, how should the valve be constructed so as to give a maximum opening of ½ square foot?

12. What is the indicated H. P. of an engine running at 120 revs. per minute, M. E. P., 25 pounds per square inch, cylinder 10 inches diameter, stroke 18 inches.

13. The diameter of a safety valve is 3½ inches, the leverage 11 : 1. Find the pull on the end of the lever when steam pressure is 100 pounds above atmosphere.

14. A weight of 5 pounds is hung at the end of a uniform bar, which is balanced over a knife edge at a point 14 inches from the end at which the weight hangs. Find the length of the bar if it weighs 30 pounds?

15. A wrought iron bar ¾ inch diameter has a modulus of

elasticity of 28,000,000 pounds per square inch. Its length is 23 inches. Find the load under which the bar will extend .015 of an inch. Find also the stress per square inch?

16. A gauge in a water pipe indicates a pressure of equal to 40 pounds per square inch. What is the height of the water above the gauge?

17. A beam of timber 2 inches broad by 3 inches deep and 4 feet long rests upon supports at its ends. The breaking load on the centre is 2,000 pounds. What would be the breaking load if the beam was 4 inches deep, 2 inches broad and 4 feet between supports but loaded 1 foot from the end.

18. Define kinetic energy. How does it differ from potential energy?

19. A shaft runs at 100 revolutions per minute and carries a 22 inch pulley which drives a 12 inch pulley upon a counter-shaft. On this shaft is a cone pulley having steps 8, 6, and 4 inches in diameter respectively, which gives motion to a similar cone on a lathe spindle. Find all the speeds of the lathe spindle, and if the lathe is back geared, the wheels having 63 teeth and the pinions 25 teeth, find all the speeds the lathe spindle can make.

20. Slide valve has 2¼ inches lap. Lead ⅛ inch greatest opening to steam 1¼ inches. If the stroke of the engine is 34 inches, find the position of the piston at cut off.

21. A pound of coal has a calorific value of 14,000 B. T. U. Assuming the boiler to utilize ¾ of this heat in evaporating water, how many pounds of steam at 250 degrees would be generated per pound coal if the feed water temperature was 110 degrees Fah.

23. Steam is admitted to an engine cylinder at 50 pounds pressure and is cut off at 1/5 stroke, back pressure 5 pounds, piston speed 300 ft. Find the diameter of the piston so that the engine shall indicate 30 H. P.? Hyp. log = 1.609.

24. Write down the formula which connects the weight of the fly wheel, its radius of gyration, the number of revolutions per minute, and the number of foot pounds of work stored up in the wheel.

25. Find the brake horse power and the working efficiency of the following engine: Cylinder diameter, 8 inches; stroke, 18

inches; number of revolutions per minute, 150; M. E. P., 35 pounds; brake wheels, 2.5 radius; effective load, 294 pounds.

26. The sum of the areas of diagrams from the two ends of a cylinder is 3.5 square inches, and the scale is 1/30 pounds. The diagram is 4¼ inches long; diameter of cylinder, 18 inches; stroke 2 ft. Find the I. H. P. of the engine when running at 60 revs. per minute.

27. In a cylindrical steam boiler prove the formula for the forces tending to produce rupture of the material in the circumferential and longitudinal directions.

28. Find the number of B. T. U. required to convert 1 pound water at 60 degrees Fah. into steam at 130 pounds pressure, the temperature being 347 degrees Fah. How many thermal units are rendered available for the burning of 1 pound coal in evaporating 8 pounds water at 60 degrees into steam at 60 pounds pressure?

29. Given Unwin's proportion for the diameter of a rivet as $1.2\sqrt{t}$ where t = thickness of the plate in inches. Find the pitch and diameter of rivet when the plate is ¾ inch thick, single, double, and triple rivetted joints.

30. What is the percentage of strength of plate to that of the original plate in No. 29, also the percentage of strength of rivet to that of the plate of the single, double and triple rivetted joints? Show clearly how you arrive at your results.

31. A shaft having a four-stepped cone revolving at 180 revs. connected by a crossed belt to another shaft having a similar stepped cone. The diameter of the largest step of the cone on the driving shaft is 16 inches. The driving shaft is required to run at 480, 300, 160, and 90 revs. per minute. Determine the diameters of the remaining steps of the two cones.

32. Determine the H. P. which may be transmitted by a leather belt 3 feet wide by ⅜ inch thick running at 75 feet per second. The tension of the slack side being equal .4 that of the tight side. Maximum stress 300 pounds per square inch.

33. Travel of valve 8¾ inches, outside lap 2¼ inches, inside lap, ¼ inch, angle of advance 35°. Find position of crank at admission, cut off, release compression, and also the amount of lead.

34. In a boiler 25 feet long, 7 feet diameter, having 2 flues 30

inches diameter, ultimate strength of double rivetted joint = 35,000 lbs. per sq. inch and single rivetted 28,000 lbs. per sq. inch. Find the bursting pressure in longitudinal and transverse seams.

35. How would you combine into one diagram the indicator cards from two cylinders of a compound engine? What data do you require in addition to the actual cards?

36. In a boiler test made recently between hand firing and the Jones Underfeed Stoker, the observed conditions were as follows:—

	HAND.	JONES.
Duration of tests	10 hrs.	10 hrs.
Coal burned	3,800 lbs.	5,000 lbs.
Total water evap'd from temp. of feed ..	26,600 lbs.	42,500 lbs.
Average steam press	93 lbs.	100 lbs.
Average feed temp	165 deg.	150 deg.

Find the relative evaporative performance and the saving in coal by the use of the Jones Underfeed Stoker, also the H. P developed and the ratios of the work performed by each.

37. The high and low pressure cylinders of a compound engine are respectively 50 inches and 90 inches diameter. The stroke is 3 feet and it makes 80 revs. per minute. The steam pressure is 80 lbs. by the gauge and the vacuum is 27 inches. The rate of expansion is 5 and the steam is cut off in the high pressure cylinders at 3/5 stroke. Receiver pressure, 22 lbs. Determine the point of cut off in the low pressure cylinder, calculate the indicated H. P. and combine into one diagram the ndicator cards from the two cylinders.

38. What would be the difference in the indicator diagrams of an engine working with steam at 120 lbs. absolute pressure, cut off at .25 of the stroke when the volume of the total clearance space (in cylinder and passages) is equal to 1/16 and 1/8 respectively of the contents of the cylinder.

39. Two engines, one having a surface, and the other a jet condenser, deliver for condensation the same weight of exhaust steam at a temperature of 150 degrees F. The circulation and injection water have the same temperature of 60 degrees F., and the hot well has a temperature of 105 degrees F., while the circulation water leaves the condenser at 90° F. Find the

amount of condensation water per pound of steam required by the respective engines.

40. Investigate the formulæ as given with Wilson Pyrometer.

$$t_1 = 62\,(t^3 - t_2) + t_3$$

41. It was found in a boiler test that the average evaporation for 10 hours was 4,000 lbs. water per hour and the average coal consumption was 400 lbs. The feed water at 40 degrees F. was pumped through an exhaust steam heater which raised the temperature to 200 degrees F. before entering the boiler. The average gauge pressure was 150 lbs. If the calorific value of the fuel was 12,800 B. T. U. per lb., calculate the efficiency of the boiler, and what horse power is the boiler developing, taking the centennial standard as your basis? What is the equivalent evaporation from and at 212 degrees? What is gained by having the feed water heater? Temperature of steam at 150 lbs. pressure is 366 degrees F.

42. The diameter of a fly wheel is 20 feet, depth of rim 12 inches, width of rim 18 inches, 80 revs. per minute. Find centrifugal force and bursting stress. Take the radius of gyration as being 9.5 lbs. Find also the maximum no. of revs. this wheel could make per minute, taking the tensile strength of good cast iron as being 20,000 lbs. per sq. inch.

By sending 25 cents in stamps to the General Engineering Co. of Ontario, an answer to any of the above will be mailed.

Equivalents of Units of Measurement.

Lengths.

UNITS.		EQUIVALENTS.	
1 mil	=	.025400	millimeter.
"	=	.001	inch.
1 millimeter	=	39.3708	mils.
"	=	.039371	inch.
1 centimeter	=	.393708	inch.
1 inch	=	2.53995	centimeters.
1 foot	=	.30479	meter.
1 yard	=	.91438	meter.
1 meter	=	39.3708	inches.

1 meter	=	3.28089	feet.
"	=	1.09363	yards.

Surfaces.

Units.		Equivalents.	
1 sq. mil	=	.000645	sq. millimeter.
"	=	.000001	sq. inch.
1 sq. millimeter	=	1550.1	sq. mils.
"	=	.001550	sq. inch.
1 sq. centimeter	=	.15501	sq. inch.
1 sq. inch	=	6.4514	sq. centimeters.
1 sq. foot	=	929.00	sq. centimeters.
1 sq. yard	=	.83610	sq. meter.
1 sq. meter	=	10.764	sq. feet.
"	=	1.1960	sq. yards.
1 sq. mile	=	640	acres.
"	=	2.5899	sq. kilometers.

Volumes.

Un[illegible]		Equivalents.	
1 cub. centimeter	=	.061027	cub. inch.
"	=	.0021135	pint.
1 cub. inch	=	16.386	cub. centimeters.
"	=	.034632	pint.
1 fluid ounce	=	29.572	cub. centimeters.
"	=	8	fluid drachms.
1 pint	=	473.15	cub. centimeters.
"	=	28.875	cub. inches.
"	=	16	fluid ounces.
1 quart	=	946.3	cub. centimeters.
"	=	57.75	cub. inches.
1 gallon	=	3785.2	cub. centimeters.
"	=	231.00	cub. inches.
"	=	.13368	cub. foot.
1 cub. foot	=	28315.3	cub. centimeters.
"	=	29.922	quarts.
"	=	7.4805	gallons.
1 cub. yard	=	201.97	gallons.
"	=	.76451	cub. meter.
1 cub. meter	=	264.19	gallons.
"	=	35.317	cub. feet.

Weight.

UNITS.		EQUIVALENTS.	
1 milligram	=	.015432	grain.
1 grain	=	64.799	milligrams.
1 gram	=	15.43235	grains.
1 ounce Avoir.	=	437.5	grains.
"	=	28.3495	grams.
1 ounce Troy	=	480	grains.
"	=	31.1035	grams.
"	=	1.0971	ounces Avoir.
1 pound Troy	=	5760	grains.
"	=	12	ounces Troy.
"	=	.82286	pound Avoir.
"	=	.37324	kilogram.
1 pound Avoir.	=	7000	grains.
"	=	16	ounces Avoir.
"	=	1.2153	pounds Troy.
"	=	.45359	kilogram.
1 net or short ton	=	2000	pounds Avoir.
"	=	.90719	metric ton.
"	=	.89286	long ton.
1 metric ton	=	2204.62	pounds Avoir.
"	=	1.1023	short tons.
"	=	.98421	long ton.
1 gross or long ton	=	2240	pounds Avoir.
"	=	1.1200	short tons.
"	=	1.01605	metric tons.

Weights and Surfaces.

UNITS.		EQUIVALENTS.	
1 pound per square inch	=	.068044	atmosphere.
"	=	.070310	klgr. per square cent.
1 atmosphere	=	760	millimeters of mercury.
"	=	33.901	feet water
"	=	14.696	pounds per square inch.
"	=	10.333	metres water.
Specific gravity mercury	=	13.596	

IMAGE EVALUATION TEST TARGET (MT-3)

6"

Weights and Volumes.

UNITS.		EQUIVALENTS.	
1 grain per cub. inch	=	.24686	lbs. per cubic ft.
" "	...=	.00395	gram per cub. cent.
1 lb. per cub. foot.....	=	4.0509	grains per cub. inch.
" "	...=	.016019	gram per cub. cent.
1 gram per cub. cent...	=	252.88	grains per cub. inch.
" "	. .=	62 425	lbs. per cub. foot.
1 lb. per cub. inch......	=	.027681	klgr. per cub. cent.

Weight of Water.

UNITS.	EQUIVALENTS.	
1 cub. centimeter weighs	15.432	grain.
" "	1	gram.
1 cub. inch	252.88	grains.
"	16.386	grams.
"	.036125	pound.
1 cub. foot....	62.425	pound.
"	28.3153	kilograms.
1 cub. yard	1685.5	pounds.
"	764.51	kilograms.
1 cub. meter.	2204.6	pounds.
1 pound water measures	483.59	cub. centimeters.
" "	27.681	cub. inches.
" "	.47933	quart.
" "	.016019	cub. foot.
1 klgr. water measures.	61.027	cub. inches.
" "	1.0567	quarts.
" "	1.	liter
" "	.035317	cub. foot.

Velocities.

UNITS.		EQUIVALENTS.	
1 foot per second.......	=	.30479	meter per second.
"	=	.011364	mile per minute.
1 meter per second.....	=	3.2809	feet per second.
"	=	.037283	mile per minute.
1 mile per minute	=	88	feet per second.
"	=	26.822	meters per second.
"	=	1.60931	kilometers per minute.

Work.

UNITS.		EQUIVALENTS.	
1 erg	=	1	dym. centimeter.
"	=	.0000001	Joule.
1 gram centimeter	=	981.00	ergs.
"	=	.00001	kilogram meters.
1 foot grain	=	1937.5	ergs.
1 Joule, or 1 volt coulomb or 1 Watt per second or 1 volt ampere per second	=	10000000	ergs.
	=	.737324	foot pounds.
	=	.101937	kilogram meter.
	=	.0013592	metric H. P. for one second
"	=	.0013406	H.P. for one second.
"	=	.0002778	Watt horse power.
1 foot pound	=	13562600.0	ergs.
"	=	1.35626	Joules.
"	=	.13825	kilogram meter.
"	=	.001818	H. P. for one second.
"	=	.0003767	Watt hour.
1 Watt hour	=	3600	Joules.
"	=	2654.4	foot pounds.
"	=	366.97	kilogram meters.
"	=	3.4383	pounds Fah. heat units.
"	=	1.9102	pound Cent. heat units.
"	=	.0013406	horse power hour.
1 horse power hour	=	2685400	Joules.
"	=	1980000	foot pounds.
"	=	2564.8	pound Fah. heat units.
"	=	1424.9	pound Cent. heat units.
"	=	745.941	Watt hours.

Heat.

1 gram Centigrade	=	.001	kilogram Centigrade
1 pound Fahrenheit	=	1047.03	Joules.
"	=	772	foot pounds.
"	=	.55556	pound Centigrade.
"	=	.29084	Watt hour.
"	=	.00039	horse power hour.
1 pound Centigrade	=	1884.66	Joules.
"	=	1389.6	foot pounds.

1 pound Centigrade	=	1.8	pound Fah.
"	=	.52352	Watt hour.
"	=	.0007018	horse power hour.

Power.

UNITS.		EQUIVALENTS.	
1 erg per second	=	.0000001	watts.
1 Watt = 1 volt ampere	=	10000000	ergs per second.
" = 1 Joule per sec	=	44.2394	foot lbs. per minute.
" = 1 volt coulomb	=	6.11622	kilogramm'trs pr. min
" per second	=	.0318360	lb. Centigrade.
" "	=	.0013406	horse-power.
1 foot lb. per minute	=	226043	ergs per second.
" "	=	·0226043	Watts.
" "	=	.000030303	horse-power.
1 horse-power	=	745.94 × 10⁷	ergs per second
"	=	745.941	Watts.
"	=	33000	foot lbs. per minute.
"	=	42.746	lbs. Fah. heat units per minute.
"	=	23.748	lbs. Cent. heat units per minute.
1 lb. Fah heat unit per minute	=	17.4505	Watts.
" "	=	.023394	horse-power.
1 lb. Cent. heat units per minute	=	31.4109	Watts.
" "	=	.042109	horse-power.

Slip of the Screw.

IF a screw worked in a solid, unyielding nut, then the distance travelled by the ship in a given time would be equal to the number of revs. made by the screw in that time multiplied by the pitch of the screw. But the water which forms the nut for the screw propeller is not unyielding. The result is that the ship does not progress a distance equal to the pitch of the screw for each revolution. The difference between the speed of the ship and the speed of screw is termed the "slip" of the screw. This, however, is only the **apparent slip**: in order to find the **real** slip the velocity of the stream of water which always follows a ship, and in which the screw works, must be known.

When a common screw works in a solid nut, it advances for each revolution a distance equal to the pitch of the screw, and the nut remains stationery; but when the nut is formed of a yielding medium, such as water, then the screw slips. The water does not remain stationary during the rotation of the screw, but is projected backward by the screw in a direction opposite to that in which the slip is travelling. The **actual** velocity of this column of water thrown back by the screw represents the true or **real slip** of the screw.

Thrust of the Screw.

WHEN a screw steamer is moving forward at a uniform speed, the reaction of the mass of water projected backwards by the propeller is exactly equal to the resistance opposed to the forward motion of the vessel. It is, therefore, absurd to attempt to get a screw to work without any slip, for if there was no **real** slip, then there would be no resultant propelling reaction.

To calculate the thrust of a jet, paddle or screw in pounds.

Multiply together the transverse sectional area in square feet of the stream of water driven astern by the propeller, the speed of the stream relatively to the ship in knots, the real slip or part of that speed which is impressed on that stream by the propeller also in knots; and the constant 5.66 for sea water, or 5.5 for fresh water.

Thus Let A = area of stream driven back in square feet.

S = speed of screw in knots per hour.

s = speed of ship "

$\therefore S - s$ = apparent slip.

Then the thrust in pounds $= A \times S\,(S - s)\,5.66$

EXAMPLE.—Find the thrust of a screw propeller 20 ft. diameter, having a hub 4 ft. diameter, when driving a ship at 14 knots an hour, slip of screw being 10%.

$A = \pi(r_1^2 - r_2^2) = 3.1416\ (10^2 - 2^2) = 301.6$ square feet.

$s = 14$ knots.

$$S = \frac{14 \times 100}{90} = 15.\dot{5}\dot{5}$$

$$\therefore = A \times S\ (S - s)\ 5.66.$$
$$= 301.6 \times 15.\dot{5}\dot{5}\ (15.\dot{5}\dot{5} - 14)\ 5.66.$$
$$= 41,143 \text{ pounds.}$$

The above formula may be expressed as follows:—

If W = weight of water acted in pounds

S = slip of screw in feet per second.

g = acceleration due to gravity = 32.2 feet per second.

$$\text{Reaction} = \frac{W\,S}{g} \text{ in pounds urging the vessel forward.}$$

Best Diameter, Revolution, and Pitch of Screw.

THE engines exist **only** to drive the propeller, and should be subordinated to it, therefore in designing the propelling machinery for a new vessel, the thing to start out with is the size of the propeller, and **not** the size of the engines. Having therefore a given speed of vessel and a given horse power to start with, fix upon the diameter of the propeller, then upon the revolutions suitable for it. With these fixed it is then an easy matter to find the size of the engine. It is therefore an entire reversal of the proper process to say "I will run my engine at such and such speed and make my propeller to suit."

Take the data from an actual propeller driving a ship of certain proportions which is known to give a good performance, and treat the same as a model for the new vessel having similar dimensions.

The diameter is proportional to the $\sqrt{\text{I.H.P.}}$, and inversely proportional to the square root of the cube of the speed.

Example.—

Let d = diameter of model propeller = 5.0 feet
D = " required " =
p = I.H.P. of model " = 670
P = I.H.P. of required " = 1800
v = speed of vessel with model propeller = 18 knots.
V = " " required " = 20 "

$$\text{Then } D = \sqrt{d^2 \times \frac{P}{p} \times \frac{v^3}{V^2}}$$

$$= \sqrt{5^2 \times \frac{1800}{670} \times \frac{18^3}{20^2}} = 7 \text{ feet.}$$

$$\text{Or } \frac{D}{d} = \sqrt{\frac{P}{p} \times \frac{v^3}{V^3}} = 1.4$$

$$\therefore D = 1.4d = 1.4 \times 5 = 7 \text{ feet.}$$

The revolutions per minute are proportional to the speed and inversely proportional to the diameter.

Let r = revolutions per minute of model propeller = 200
R = " " required "

$$\text{Then } R = r \times \frac{V}{v} \times \frac{d}{D}$$

$$= 200 \times \frac{20}{18} \times \frac{5}{7} = 159 \text{ revolutions.}$$

If the model used is larger the ratios are reversed.

The pitch of the propeller should then be made the same ratio to the diameter as in the model. The pitch should never exceed 2½ times the diameter.

Jet Propulsion.

THE theory of the jet-propeller is similar to that of the screw-propeller. If A = area of the jet in square feet, V = the velocity in feet per second, with reference to the orifice, v =

velocity of the ship, then the thrust of the jet is 2 AV (V-v). The work done on the vessel is 2 AV (V-v) v, and the work wasted on the rearward projection of the jet is AV (V-v)². The efficiency is $\frac{2v}{V+v}$ This is equal to unity when the velocity of the jet is equal the velocity of the ship in reference to the earth, or V=v; this is only the case when V-v=0, or when the thrust of the propeller is 0. The greater the value of V compared with v, the less the efficiency.

Rankine showed in 1867 that the greater the quantity of water operated on by a jet-propeller the greater the efficiency. Experiments with Jet Propulsión have all resulted in failure. The "Waterwitch" built by the British Government gave an efficiency of only 18%. The "Squirt," a small torpedo boats built also by the British Government, gave a speed of 12 knots per hour as against 17 knots by a sister ship, having a screw and equal steam-power.

In defiance of theory and of the earlier experiments and of the opinions of many naval engineers, two experimental boats were built in New York, viz., "Prima Vista" and the "Evolution," in which the jets were made very small, and the pressure 2,500 lbs. per square inch. Over $300,000 were spent, but as was predicted, the whole thing was a failure. Rankine sums up the whole theory of jet propulsion in the following words:—

"That propeller is the best, other things being equal, which drives astern the largest body of water at the lowest velocity." It is practically impossible to devise any system of hydraulic or jet propulsion which can compare favorably, under these conditions, with the screw or the paddle-wheel.

Water Consumption

From the Indicator Diagram.

IF an engine were driven by any liquid weighing 1 lb. per cubic inch it would consume 23,760,000 inch pounds per hour. As there are 62.5 lbs. water per cubic foot, we have therefore, 27.648 cubic inches per lb. of water. If we divide 23,760,000 by 27.648 we get 859 375 lbs. of water at 1 lb. M. E. P. to develop one horse power.

If, however, the pressure be more than 1 lb., then the power developed will be proportionately greater for the same consumption and will consume proportionately less water in proportion as the water for the steam used is less in volume than the steam; it follows that the constant 859,375 divided by the M. E. P. of any diagram and by the volume of its terminal pressure will give the rate of water consumption per I. H. P. per hour.

The terminal pressure is the pressure that would be in the cylinder if release did not occur until piston had come to end of the stroke.

$$\text{Or } \frac{859{,}375}{\text{M. E. P.} \times \text{vol. of terminal pressure}} = \text{Water consumption per I. H. P. per hour.}$$

EXAMPLE.—

M.E.P. = 62 lb.

Terminal pressure = 35 lb.

Relative volume of steam to that of water at that pressure = 726

$$\therefore \frac{859375}{62 \times 726} = 19 \text{ lb}+.$$

Instead of taking the terminal pressure in the diagram it may be advisable to take any point in the expansion curve. Suppose we have a diagram $4\frac{1}{2}$ inches long and a certain point in the curve measures 90 lbs. from vacuum, and that the distance from this point to the admission is $1\frac{7}{8}$ inches, then the number 859375 is multiplied by the length of the consumption line ($1\frac{7}{8}$ inches) and divided by the M.E.P. × volume × length of the diagram, or $\dfrac{859375 \times 1\frac{7}{8}''}{62 \times 298 \times 4\frac{1}{2}} = 19$ lb. +

298 being the volume of steam at 90 lbs. absolute.

The following table of constants has been calculated to enable calculations of water consumption to be quickly made, the constant being equal to the number 859375, divided by the volumes at the various pressures:—

Terminal Pressure Absolute	Constant	Terminal Pressure Absolute	Constant	Terminal Pressure Absolute	Constant
1	41.6	26	906.1	51	1721.9
2	80.1	27	939.6	52	1753.5
3	117.4	28	973.0	53	1785.1
4	153.4	29	1006.3	54	1817.8
5	189.3	30	1039.4	55	1849.5
6	225.4	31	1072.6	56	1880.5
7	260.4	32	1106.0	57	1911.4
8	295.4	33	1138.6	58	1942.5
9	329.2	34	1171.6	59	1974.2
10	364.2	35	1204.8	60	2005.6
11	398.9	36	1237.4	61	2036.4
12	465.8	37	1270.1	62	2067.7
13	499.2	38	1302.6	63	2098.8
14	522.7	39	1335.3	64	2129.8
15	533.1	40	1368.0	65	2160.9
16	567.5	41	1401.0	66	2191.8
17	601.4	42	1433.8	67	2222.9
18	636.4	43	1467.8	68	2253.8
19	670.0	44	1498.0	69	2285.0
20	704.3	45	1531.4	70	2315.1
21	738.0	46	1561.3	71	2345.3
22	770.1	47	1591.2	72	2375.8
23	805.4	48	1624.5	73	2406.5
24	839.0	49	1657.1	74	2437.2
25	872.5	50	1690.0	75	

Example in working the table:

M.E.P. = 62 lbs.; terminal pressure, 35 lbs. What is the water consumption?

Find constant corresponding to the pressure and divide by the M.E.P., or $\frac{1204.8}{62} = 19.4$ lbs. +

Example 2.—

Consumption line 2", length of diagram 4".
M.E.P. = 30 lbs. Pressure at point in curves 45 lbs. Find water consumption.

$$\frac{1531.4 \times 2}{30 \times 4} = 25.5 \text{ lbs.}$$

Belting.

The ultimate strength of ordinary bark-tanned single leather belting varies from 3000 to 5000 pounds per square inch of cross section.

The thickness of single belting varies from 3/16 inch to 5/16 inch, and from 3/8 to 5/8 inch for double belting, and by taking the mean thicknesses we get the breaking stresses from 750 to 1250 pounds per inch of width for single belts and 1500 to 2500 pounds for double belts.

The **safe working tension** should never exceed **one-fifth** of the strength of the joint which is about one-third the above values. From this we find that by taking 1/5 of 1/3 of the breaking stress, or 1/15, the working tensions are

for single belting, 50 to 80 pounds
for double belting, 100 to 160 pounds.

Belts will run with the minimum of attention for many years, if the tensions do not exceed 50 pounds for single and 80 pounds for double belts per inch of width.

Horse Power that Leather Belts will Transmit per Inch of Width at Various Speeds.

Velocity of Belt in feet Per Minute.	Best Oak Tanned Belts.			Velocity of Belt in feet Per Minute.	Best Oak Tanned Belts.		
	Single.	Light Double.	Heavy Double.		Single.	Light Double.	Heavy Double.
100	.15	.21	.27	2100	3.18	4.45	5.73
200	.30	.42	.55	2200	3.33	4.67	6.00
300	.45	.64	.82	2300	3.49	4.88	6.27
400	.61	.85	1.09	2400	3.64	5.09	6.55
500	.76	1.06	1.36	2500	3.79	5.30	6.82
600	.91	1.27	1.64	2600	3.94	5.52	7.09
700	1.06	1.49	1.91	2700	4.09	5.73	7.36
800	1.21	1.70	2.18	2800	4.24	5.94	7.64
900	1.36	1.91	2.45	2900	4.39	6.15	7.91
1000	1.51	2.12	2.73	3000	4.50	6.36	8.18
1100	1.67	2.33	3.00	3100	4.60	6.58	8.45
1200	1.82	2.55	3.27	3200	4.69	6.79	8.70
1300	1.97	2.76	3.55	3300	4.77	7.00	8.86
1400	2.12	2.97	3.82	3400	4.84	7.21	8.96
1500	2.27	3.18	4.09	3500	4.90	7.31	9.06
1600	2.42	3.39	4.36	3600	4.95	7.40	9.16
1700	2.58	3.61	4.64	3700	4.99	7.48	9.24
1800	2.73	3.82	4.91	3800	5.03	7.54	9.29
1900	2.88	4.03	5.18	3900	5.05	7.60	9.34
2000	3.03	4.24	5.45	4000	5.08	7.64	9.37

References.

THE Improved Jones Underfeed Stoker and Smokeless Furnace has been installed in the best plants in Canada and the United States, and the following partial list of users in Canada will impress those interested to a far greater degree than copies of testimonials.

We would refer all interested in the reduction of their fuel bills to any of the following :—

WINDSOR HOTEL.................... ......Montreal, Que.
BELL TELEPHONE CO., Aqueduct St.....   "   "
DOMINION OIL CLOTH CO..................   "   "
MONTREAL ROLLING MILLS...... .....   "   "
CRESCENT CEMENT WORKS..............   "   "
C.P.R. DALHOUSIE SQUARE STATION....   "   "

E. B. EDDY CO.	Hull, Que.
LONDON ELECTRIC LIGHT CO.	London, Ont.
JOHN LABATT	" "
THE RIORDAN PAPER MILLS	Merritton, Ont.
ORILLIA ASYLUM, Ontario Government	Orillia, Ont.
KINGSTON PENITENTIARY, Dom. Gov't.	Kingston, Ont.
J. CAMPBELL	St. Thomas, Ont.
O'KEEFE BREWERY CO	Toronto, Ont.
TAYLOR BROS. PAPER MILLS	" "
THE T. EATON CO	" "
THE FORESTERS TEMPLE	" "
THE NEW MUNICIPAL BUILDINGS	" "
WATER WORKS, High Level Pumping Station	" "
TORONTO ELECTRIC LIGHT CO.	" "
ONTARIO POWER AND FLATS CO., Niagara St.	" "

The Steam Jacket.

THERE is a great diversity of opinion as to the efficiency of the Steam Jacket. Numerous tests on various engines with and without jackets show results varying from 30% down to zero, and in some cases an actual loss.

Professor Unwin says that there was no trustworthy engine test which showed a greater steam consumption with than without the Steam Jacket. He considers that in all cases, and on all cylinders, the jacket is useful, providing ordinary and not superheated steam is used, but the advantages may diminish to an amount not worth the interest on the extra cost.

The jacket is most useful in cases where the initial condensation is greatest, such as in small and slow-speed engines. The jacket is the least useful in engines which are most scientifically designed and of the highest class. Experiments made with Corliss engines demonstrate that the jackets effect a 1.5% saving.

Professor Cotterill states, experience shows that the steam jacket is advantageous, but the amount gained varies according to circumstances. In many cases it may be that the advantage is small. Great caution is necessary in drawing conclusions from any special set of experiments on the influence of the Steam Jacket.

Professor Witz made very accurate experiments with a compound engine of 600 indicated h.p., with jackets on both cylinders, and also on the receiver. The total condensation in the jackets was 12% of the steam used, and yet the saving was only 4%. In another test made by Carpenter of a 9 x 16 x 14″ stroke 100 h.p. engine, there was very little saving made by the jackets, and when the engine was running above its rated load the jackets were detrimental, the saving being a minus quantity. As the load was reduced the jackets showed considerable saving. From this we can see that the various results obtained by the different experimenters may be due to the fact that the loads were not altogether of a suitable nature to get the best effects from the jackets. It would appear, however, if the engines were properly designed, the jacket is of little use, and it is not by means of the jacket that the waste due to cylinder condensation can be got rid of, or the highest economy reached.

Cleaning Fires.

WHAT does cleaning a fire mean? It means a great deal. It means sometimes the steam pressure will fall from 100 to 60 pounds or even lower and that it is an impossibility to raise it until some of the load is taken off, which is not always possible.

In some places it means that when a clinker has **run** all over the grates the fireman has to let one side of his fire "out" to let its grates cool down before the clinker can be removed, which also means exceedingly hard work for him trying to keep the steam up on his other boilers. No matter how hard he works or how hard he swears, down goes the steam, and by and by "**we have to shut down.**"

With the Jones Underfeed system the cleaning of the fires is a very simple matter. In plants where 300 to 400 pounds coal are burned per hour per boiler, it is only necessary to clean them once a day. The operation, however, is so simple that it scarcely enters into consideration at all. A furnace can be completely cleaned in 1½ minutes. All that is necessary is to pull out a clinker on each side of the retort and the job is done. The clinker **does not** and **cannot stick** to the dead plates as it does to grate bars. It forms all along the dead plate and comes out all in **one piece**. Steam pressure cannot fall, it invariably goes up. It is possible to run boilers 100% above their rating, and clean fires without the steam pressure varying. This is done right along. Can this be done with any other device known?

Enquire from parties who are using the Stokers as to the great ease in cleaning the furnaces, or better still, go and see them, and investigate for yourself and after that have the Stokers installed.

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