# STEAM

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# ERATA.

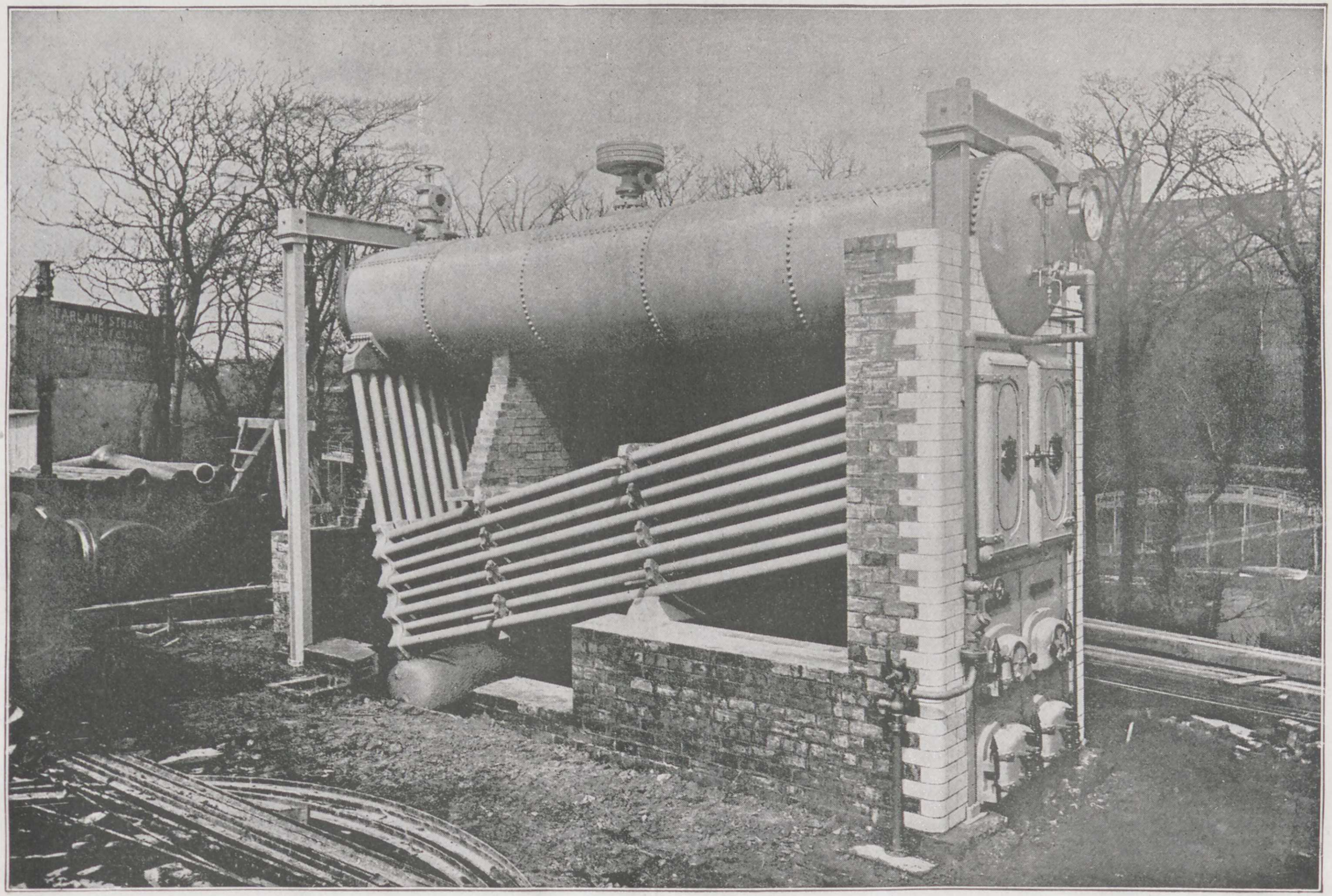
On page 15, first line, read *$H_2O$*, instead of "H O."

On page 23, under cut, read *Stevens*, instead of "Stephens," and below, *John Cox Stevens*, instead of "John Cox Stephens."

On page 51, second line, read, *Calorie*, instead of "Caloric."

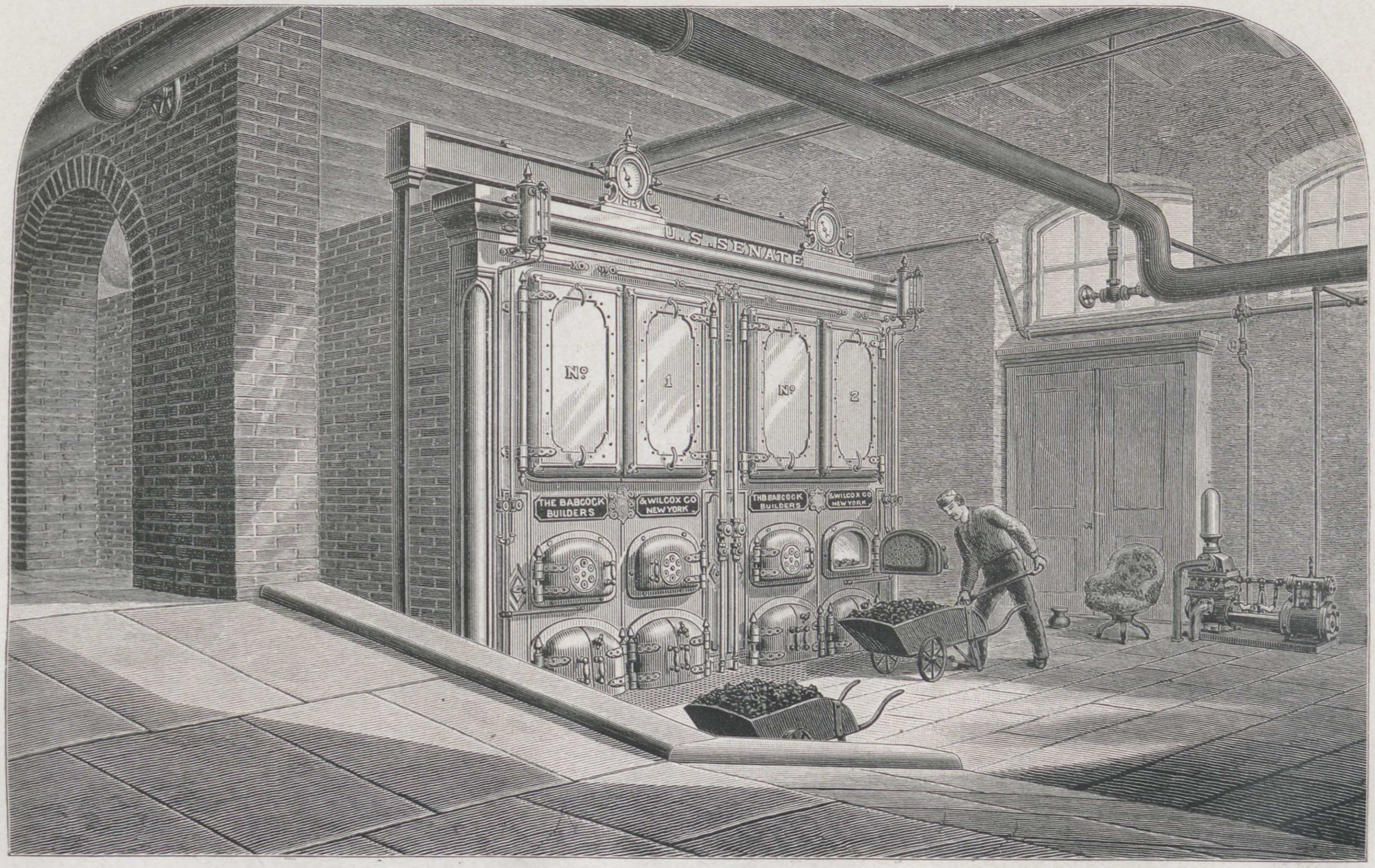
On page 60, fill blank in second column, eighteenth line from bottom, with the number "62."

On page 95, fourth paragraph, read, *Louisville*, instead of "Lexington."

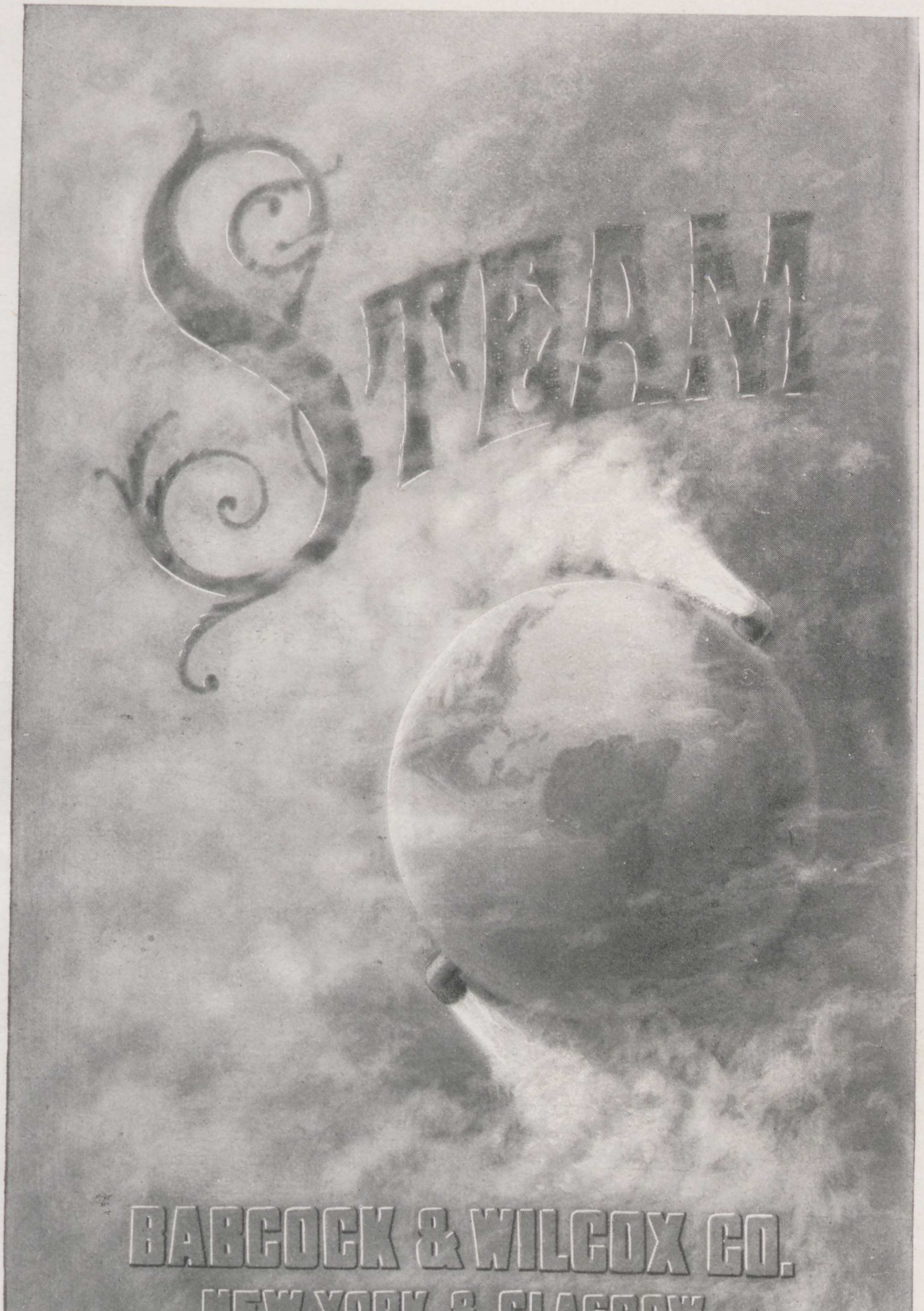


Babcock & Wilcox Boiler at Glasgow Exhibition, 1888. "W. I. F." Style, with Wrought Headers.

Press of the "American Art Printer,"
22 College Place, New York,
U. S. A.




Babcock & Wilcox Boilers in Senate Wing, United States Capitol, Washington, D. C., 312 H. P.




*English Edition Entered at Stationers' Hall.*

# STEAM:

ITS

# GENERATION · AND · USE.

WITH

## CATALOGUE OF THE MANUFACTURES

OF

## The Babcock & Wilcox Co.

30 CORTLANDT STREET, NEW YORK.
107 HOPE STREET, GLASGOW.

*Twentieth Edition, Revised and Enlarged, - - January, 1889.*

# PREFACE.

(*To First Edition, 1879.*)

WHILE making known the character and quality of our manufactures, we have endeavored at the same time to present to our friends and customers a variety of useful information, not readily accessible to them in other ways. The facts and figures herein given are derived largely from practical experience, and can be depended upon as correct. Very few of them were ever published before, while those derived from the researches of others have been simplified and adapted to the wants of manufacturers. It is with the intention, at some future time, to collect them with others into a more permanent form, that they have been copyrighted.

(*To Eleventh Edition, 1883.*)

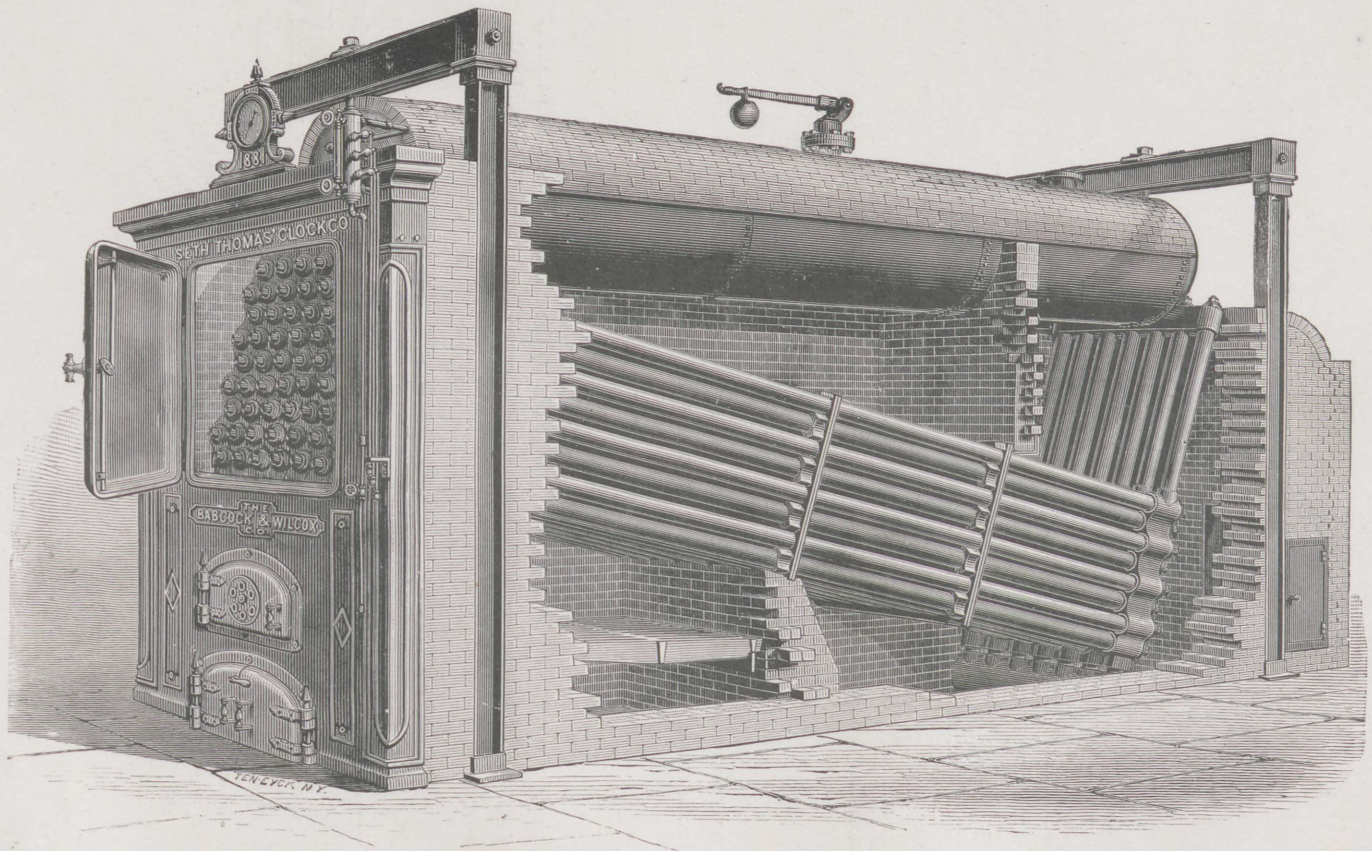
In preparing a new edition of "STEAM," we have revised the whole, and added much new and valuable matter, which we trust our customers will find useful and interesting.

(*To Thirteenth Edition, 1885.*)

Having again revised "STEAM," and enlarged it by the addition of new and useful information, not published heretofore, we shall feel repaid for the labor, if it shall prove of value to our customers.

(*To Twentieth Edition, 1889.*)

Over 75,000 copies of "STEAM" have been issued in the long form, in which it was formerly published. But many having expressed a desire to have it in a shape suitable for a library, and it becoming necessary to make new plates, the work has been again carefully revised, much new matter added, and the form changed to large octavo. It is hoped that in its new form, and with its additional matter, it will prove even more useful to the public.




Babcock & Wilcox Boilers, 125 H. P. at the Seth Thomas Clock Co., Thomaston, Conn. Erected 1880.


## ECONOMY AND SAFETY IN STEAM GENERATION.

ECONOMY IN THE USE OF COAL is a matter of great and growing importance. It is estimated that the annual production of coal in the world at the present time is not far from 400,000,000 tons. The report of the Royal Commission in England in 1870, shows the distribution at that time to have been as follows:

| | |
|---|---|
| Metallurgy and Mines, - - - - - - | 44 per cent. |
| Domestic purposes, including gas and water, - | 26 " " |
| General Manufacturing, - - - - - | 25 " " |
| Locomotion by sea and land, - - - - | 5 " " |

As a considerable part of the coal used in metallurgy and mines, as also that for domestic water supply, is used for power, we shall not be far wrong in estimating that one-half of all the coal mined, or 200,000,000 tons annually, is used for making steam. A low estimate of the value of this coal at the place of use would be an average of $2.50 per ton, which gives as the present annual expenditure for steam, a sum equal to $500,000,000; from which it will be seen how largely even a small per cent. of saving would add to the wealth of the world.

It is estimated that of the steam-power at present in use in the world, 80 per cent. has been added in the last twenty-five years, so that these figures are none too large for the present time.

While manufacturers and engineers have given much care to the improvement of the steam engine, whereby they might reduce the consumption of steam for a given amount of power, but little attention, comparatively, has been given to securing economy in its generation. In fact, the boilers in use at the present day, are substantially the same as were in common use at the close of the last century, and but slight advance has been made in their economy. Of late years, however, steam users have begun to realize that there are principles and aims of equal prominence, and greater importance, to be considered in choosing a boiler, to the selection of a steam engine.

Engineering experience and scientific investigation have established the following as the

***Requirements of a Perfect Steam Boiler.***

1st. The best materials sanctioned by use, simple in construction, perfect in workmanship, durable in use, and not liable to require early repairs.

2d. A mud-drum to receive all impurities deposited from the water in a place removed from the action of the fire.

3d. A steam and water capacity sufficient to prevent any fluctuation in pressure or water level.

4th. A large water surface for the disengagement of the steam from the water in order to prevent foaming.

5th. A constant and thorough circulation of water throughout the boiler, so as to maintain all parts at one temperature.

6th. The water space divided into sections, so arranged that should any section give out, no general explosion can occur, and the destructive effects will be confined to the simple escape of the contents; with large and free passages between the different sections to equalize the water line and pressure in all.

7th. A great excess of strength over any legitimate strain; so constructed as not to be liable to be strained by unequal expansion, and, if possible, no joints exposed to the direct action of the fire.

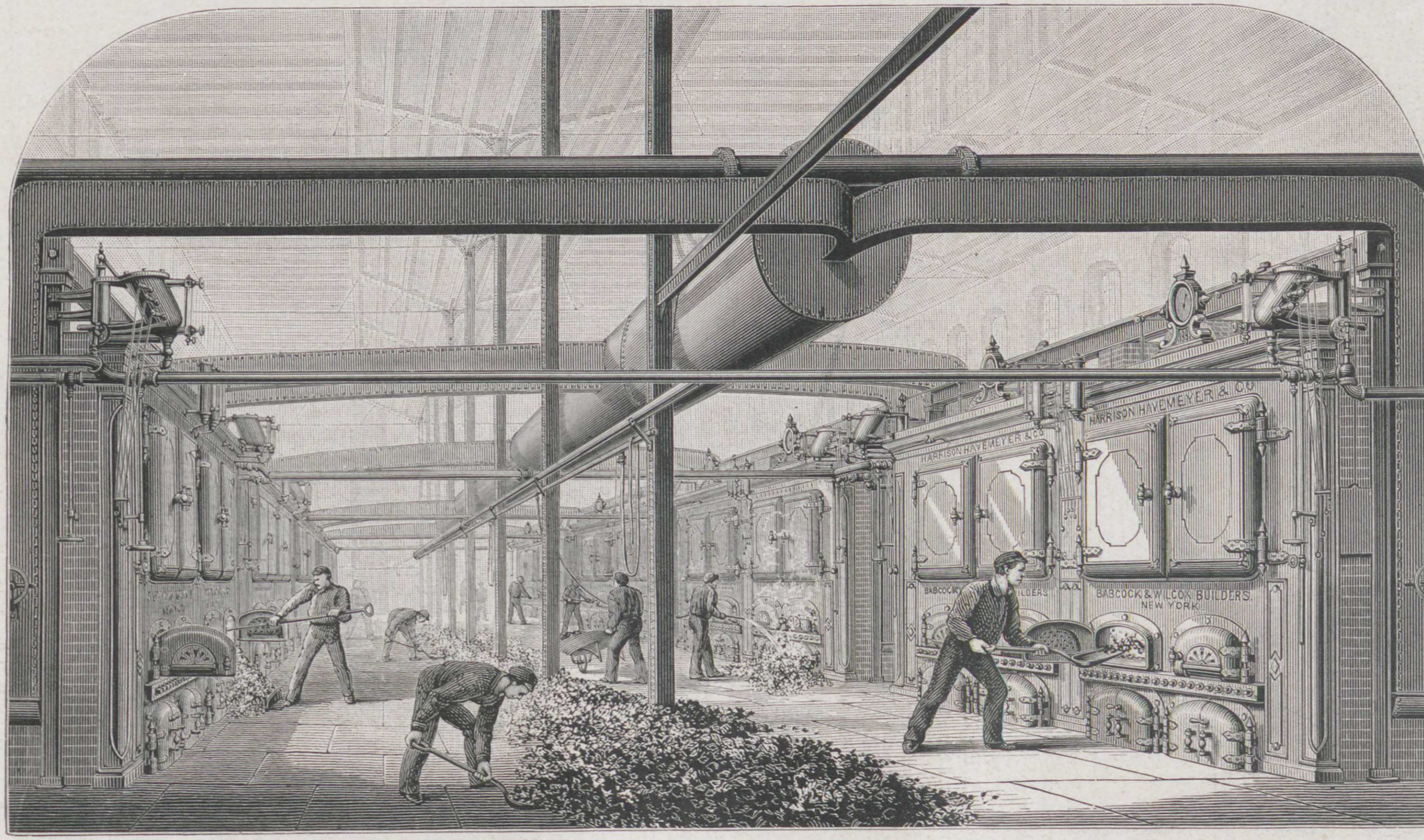
8th. A combustion chamber, so arranged that the combustion of the gases commenced in the furnace may be completed before the escape to the chimney.

9th. The heating surface as nearly as possible at right angles to the currents of heated gases, and so as to break up the currents and extract the entire available heat therefrom.

10th. All parts readily accessible for cleaning and repairs. This is a point of the greatest importance as regards safety and economy.

11th. Proportioned for the work to be done, and capable of working to its full rated capacity with the highest economy.

12th. The very best gauges, safety valves, and other fixtures.



Perspective View of the Fire Room of Harrison, Havemeyer & Co., Philadelphia, Pa. 5040 H. P., Babcock & Wilcox Boilers.

### *Importance of Providing Against Explosion.*

That the ordinary forms of boilers are liable to explode with disastrous effect, is conceded. That they do so explode is witnessed by the sad list of casualties from this cause every year, and almost every day. In the year 1880, there were 170 explosions reported in the United States, with a loss of 259 lives, and 555 persons injured. In 1887 the number of explosions recorded were 198, with 652 persons either killed or badly wounded. The average reported for ten years past has been about the same as the two years given, while doubtless many occur which are not recorded.

There is no need to resort to mysterious causes for the destructive energy displayed in a boiler explosion, for there is ample force confined within it to account for all the phenomena. Prof. Thurston* estimates that there is sufficient stored energy in a plain cylinder boiler with 100 lbs. pressure of steam to project it to a height of over three and one-half miles; a "two-flue" boiler about two and one-half miles; a "locomotive" at 125 lbs. from one-half to two-thirds of a mile; and a 60 H. P. return "tubular" at 75 lbs. somewhat over a mile high. He says, "a cubic foot of heated water under a pressure of 60 to 70 lbs. per square inch, has *about the same energy as one pound of gunpowder*. At a low, red heat, it has *about forty* times this amount of energy in a form to be so expended." Speaking of water-tube boilers he says: "The stored available energy is usually less than that of any of the other stationary boilers, and not very far from the amount stored, pound for pound, in the plain tubular boiler. It is evident that their admitted safety from destructive explosion does not come from this relation, however, but from the division of the contents into small portions, and especially from those details of construction which make it tolerably certain that any rupture shall be local. A violent explosion can only come of the general disruption of a boiler and the liberation at once of large masses of steam and water."

The Hartford Steam Boiler Inspection and Insurance Company report that up to January 1, 1888, they had inspected in all, 799,582 boilers, and had discovered 522,873 defects, *of which 93,022 were considered dangerous*. If now the above were a fair average of the boilers in ordinary use—and who shall say they are not?—we have the startling fact that *more than one boiler in nine* in common use, is in a "dangerous condition." That more do not explode, is probably due less to intelligent watchcare than to the fortunate lack of all the necessary conditions existing at one time.

* Transactions Am. Soc. Mec. Eng., Vol. 6, page 199.

### *Causes of Explosion.*

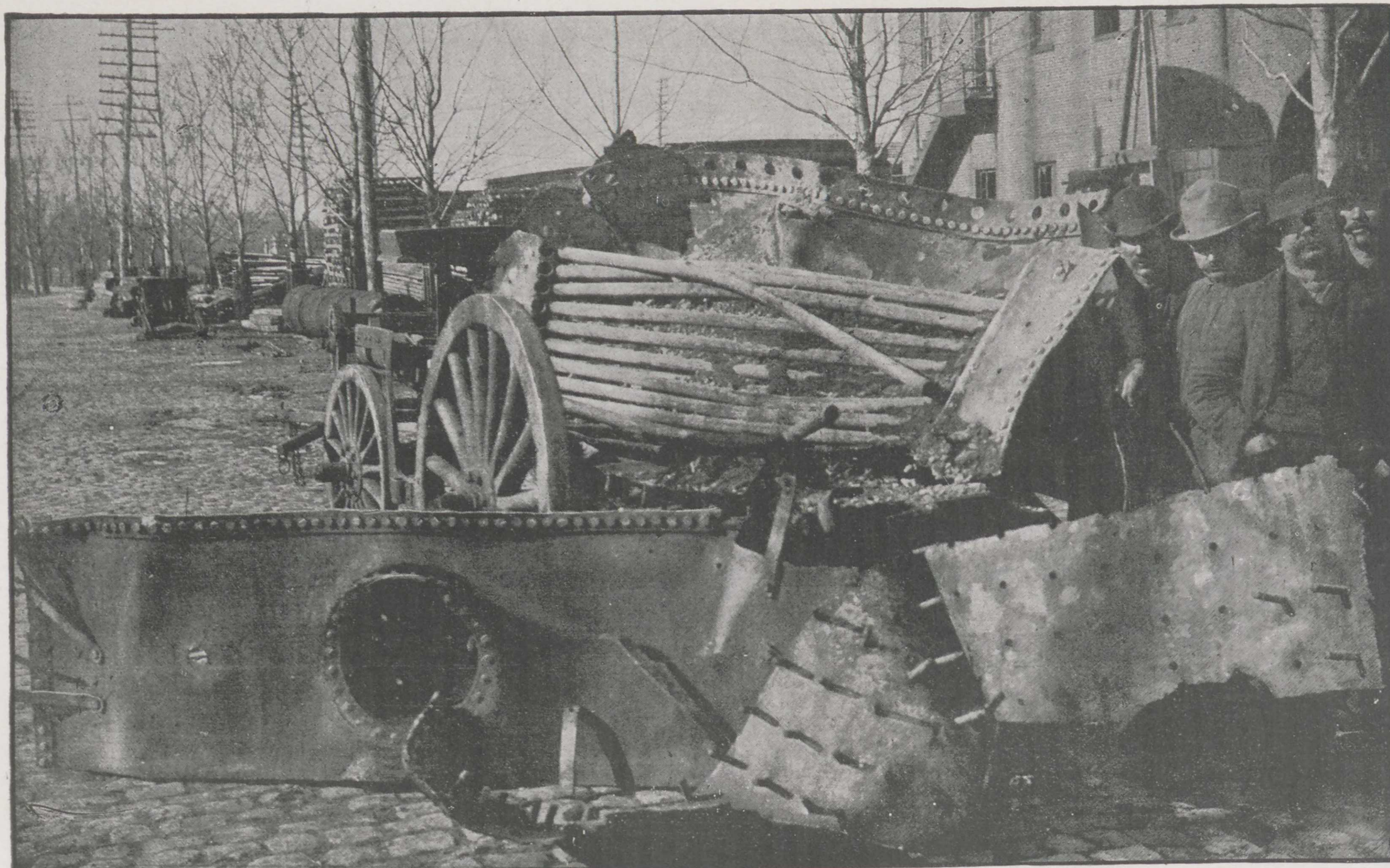
It is now fully established by the experience of Boiler Insurance Associations in this country and England, that all the mystery of boiler explosions consists in a want of sufficient strength to withstand the pressure. This lack of strength may be inherent in the original construction, but is most frequently the effect of weakening of the iron by strains due to unequal expansion caused by unequal heating of different portions of the boiler; or it may be due to corrosion from long use or improper setting.

If steam boilers are properly proportioned and constructed, they will, when new, be safe against considerably more pressure than the safety valve is set to; and the hydrostatic test, properly applied, may discover faults in material, or the weakening effects of corrosion; but, against the danger resulting from unequal expansion, ordinary boilers have no protection; a fact not properly appreciated by engineers or the public.

In getting up steam many boilers will be very hot in some parts, while other parts will be actually cold; of course, under these conditions, enormous strains must occur in some portions of the boiler, which are thereby weakened; and these strains being repeated every time steam is raised, if at no other time, will eventually so far destroy the strength of the line or point of greatest strain that rupture must result; generally the rupture is small and gradual, but sometimes large and productive of disastrous explosions. In the boilers examined by the Hartford Boiler Insurance Company, up to 1888, 24,944 fractures in plates were found in, at, or near the seams or through the line of rivets, 11,259 of which, or nearly one-half, had arrived at a dangerous state before discovery.

Want of circulation of the water in boilers is a frequent and prolific cause of unequal expansion, and deteriorating strains, and little, if any, provision is made for circulation in all ordinary construction of boilers. Another source of danger in all ordinary boilers is low water; and constant vigilance is required to keep the water at a proper height. In many boilers the fall of only a few inches in the water-line will cause the crown-sheet or some other portion to be exposed to the direct action of the fire, whence it becomes quickly over-heated, and weakened to such an extent that an explosion is likely to occur.

Another frequent cause of unequal expansions, and also of weakening by burning and blistering the iron, is the presence of deposit or scale on the heating surface. This is liable to occur in any boiler, but in very many there is no adequate provision for removing it when formed. This is



Wreck of 30 H. P. Boiler. Exploded January 9th, 1888, at Dripp's Boiler Shop, Washington, D. C. Showing insecurity of stayed surfaces.

particularly the case with "tubular" and "locomotive" boilers.

There is good reason for believing that most of the mysterious explosions of boilers which stand the Inspector's test, and then explode at a much less pressure, are due to the weakening effects of unequal expansions, for a boiler that will stand a hundred pounds test this week cannot explode the next week at fifty pounds pressure, unless it has suddenly become wonderfully reduced in strength, and no corrosion or other natural cause, with which we are acquainted, save expansion, can produce this result. When we consider that strains from difference of expansion are generally greatest when firing up, and when there is no pressure in the boiler, we can see that the time may arrive when a crack is started or the parts weakened, so as to give way under a moderate pressure just after the test has been made; and this is the probable reason why so many boilers explode in getting up steam, or so soon after, or upon pumping in cold water, or, even, as in a recent case in England, while cooling off.

### *How to Provide Against Explosions.*

Very much thought and experiment have been expended on this problem, but though many forms of boilers have been produced, which have attained practical safety from explosion, yet in nearly all of them there have been ignored certain elements necessary at the same time to make them valuable as generators of steam for practical work. Hence, the very name of "safety boiler" has unfortunately become, to some persons, *prima facie* evidence of undesirability. But safety is not incompatible with any of the other essentials of a perfect steam generator, and may be secured without detracting from any other desirable feature.

The first element of safety is ample strength This can be best attained in connection with thin heating surface, by small diameters of parts; but this must not be carried so far as to antagonize the equally important features of large capacity and disengaging surface.

The second and most important element of safety, is such a structure that the original strength cannot be destroyed by deteriorating strains, from expansion or otherwise. This can be attained in two ways — by rendering unequal expansion impossible, or by providing such elasticity that, should it occur, it can produce no deteriorating strain.

The third element of safety is such an arrangement of parts that when, through gross carelessness or design, the water becomes low and the boiler overheated, a rupture, if it occur, can produce no serious disaster.

No surface which requires to be "stayed" should be permitted in a boiler. It is scarcely possible, and altogether improbable, that such stays are, or can be, so adjusted as to bear equal strains. The one sustaining the heaviest strain gives way, the others follow, as a matter of course, and a disastrous explosion ensues. The photographic view of the boiler which exploded at Washington, January 9, 1888, shows how stay bolts act, and the disastrous explosion at West Chester, Pa., about the same time, was clearly due to the giving way of the stays which were intended to support the head.

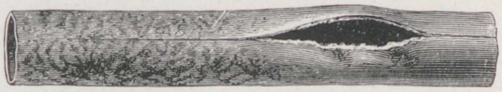
### *Water-tubes an Element of Safety.*

[*From the Manufacturer and Builder*, *Feb.*, 1880.]

Some recent actual occurrences have a very suggestive bearing upon the relative degree of immunity from violent and disastrous explosions possessed by the water-tube and fire-tube systems of boiler construction respectively.

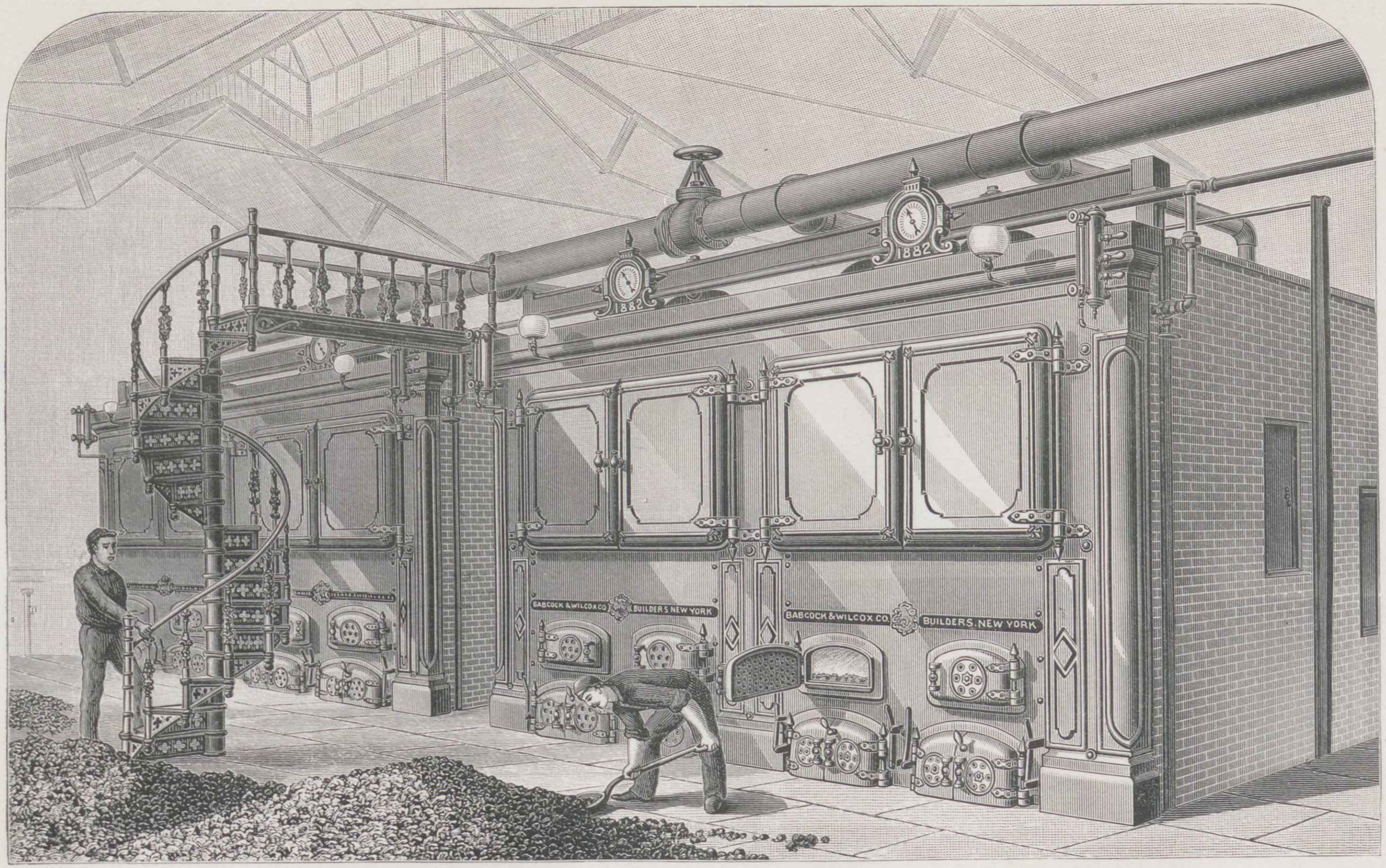
The first case is that of an accident resulting through gross carelessness to a steam boiler on the water-tube system as constructed by Messrs. Babcock & Wilcox. The circumstances of the case were such as to make the test to which the boiler was put a most severe one, and the fact that the result was *not* a disastrous explosion, scores several points in favor of the water-tube system.

The boiler here referred to is located in the Brooklyn Sugar Refinery, and is rated at 300 horse-power, being one of a set of 1500 H. P. Recently, by one of those oversights that now and then cost scores of lives under the same circumstances, the feed-water was cut off, and not noticed until the water level became so low that



the boiler was nearly empty and the tubes were overheated. The result is shown above. One of the tubes burst, and this was the extent of the damage, which was speedily repaired at a cost of $15, and the works were running the next day.

The second case is very analogous, but is even more instructive, as the boiler was subjected to a severer ordeal than the other. This boiler is in the Elizabeth (N. J.) jail, and was one of the same kind as that in the foregoing case. It was in charge of one of the convicts, who, after starting the fire as usual in the morning, was surprised not to observe, after an hour or so of waiting, any signs of activity in his steam gauge.




832 H. P. Babcock & Wilcox Boilers for Bemis & McAvoy Brewing Co., Chicago, Ill.

This fact was disclosed to some of the officials of the prison, and an investigation was instituted to ascertain the cause, disclosing a fact that at once relieved the boiler from any responsibility for the absence of steam—for there was no water in it. It also showed that the blow-cock was wide open, and had been since the night before. What followed, we give in Mr. Watson's own words:

"After the syndicate had opened the furnace door and seen the white hot tubes, it was thought a good idea to get some water in the boiler as quickly as possible; so they shut the blow-cock and turned on the city water. The result justified their expectations; steam was made very quickly; for a moment it roared through the safety valve with a fearsome sound; and that is all that happened, beyond the renewal of a few of the tubes, and one steel casting."

What might have happened had either of these boilers been fire-tube instead of water-tube boilers, we do not pretend to say, but think Mr. Watson is not far out of the way in venturing the statement that "it is not contrary to precedent to say that, in all probability, there would have been an opportunity for a coroner's inquest and a new jail."

### *Caution Necessary.*

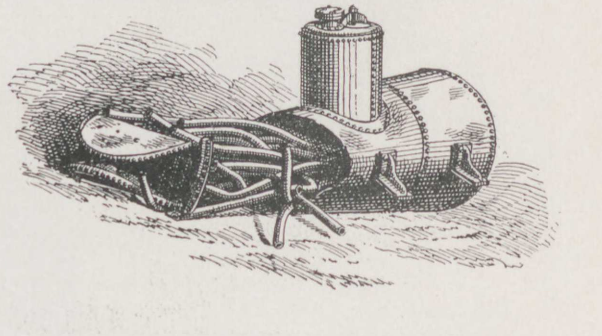
It must not be assumed, however, that the mere presence of water tubes in a boiler will make it safe. On the contrary they may be combined with other features exceedingly dangerous, such as flat surfaces, stayed or unstayed, as in the "Phleger" boiler, which exploded in Philadelphia some years ago, and the "Firminich" boiler which exploded in St. Louis, Oct. 3d, 1887. A number of porcupine boilers have also been put forth as "safe" because of their water tubes, though the large central shell is made like perforated card-board, by the numerous holes. To make the matter worse, expanding the tubes into these holes seriously strains the metal, making a weak construction weaker still.

That a boiler can be made so as to be practically safe from explosion is a demonstrated fact of which no one at all acquainted with modern engineering has any doubt. Of this class of boilers the Babcock & Wilcox is a preëminent example, from the length of time which it has been upon the market, the large number which have been for years in use under all sorts of circumstances and conditions and under all kinds of management, without a single instance of disastrous explosion.

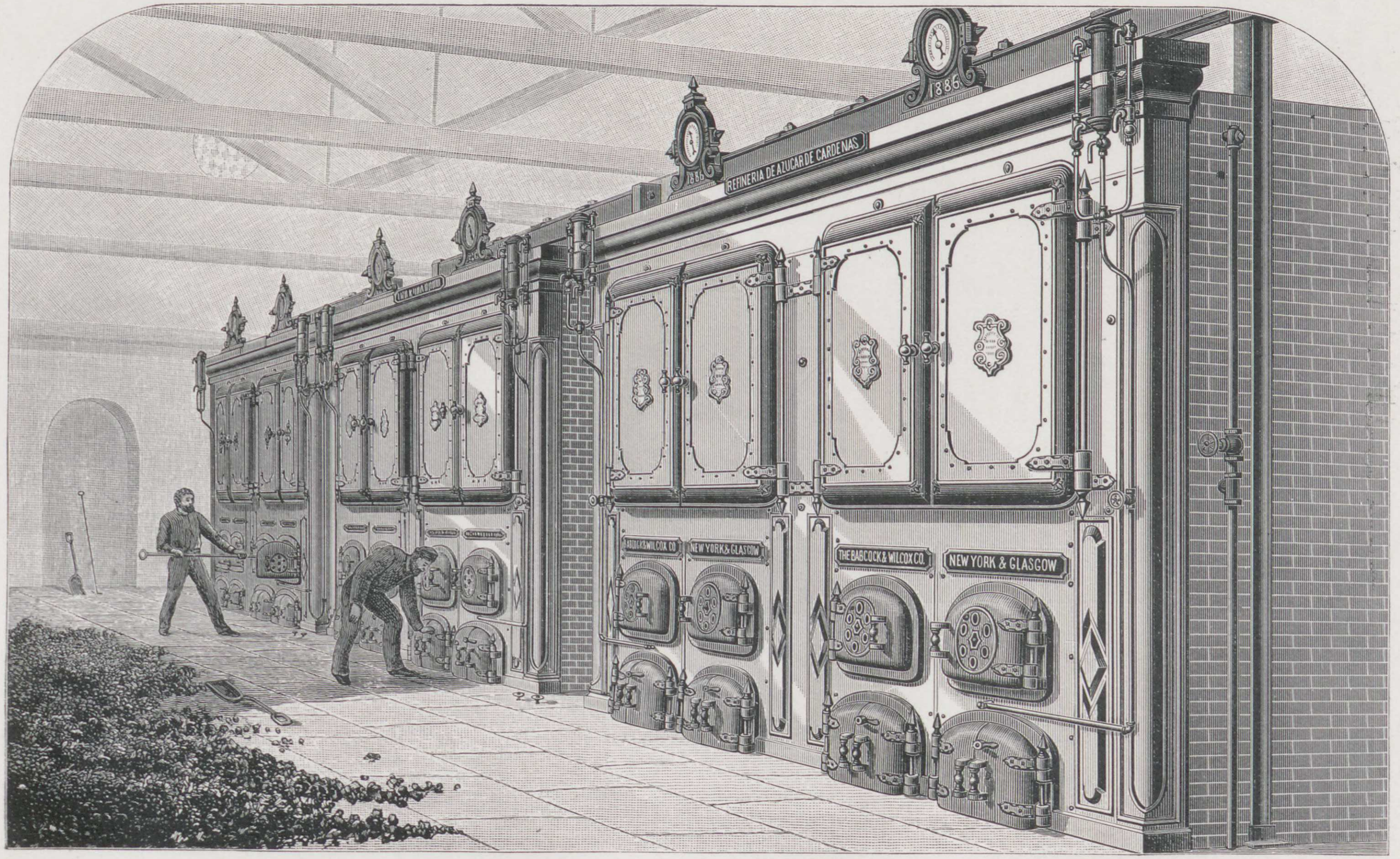
THE BABCOCK & WILCOX WATER-TUBE BOILER has all the elements of safety, in connection with its other characteristics of economy, durability, accessibility, etc. Being composed of wrought iron tubes, and a drum of comparatively small diameter, it has a great excess of strength over any pressure which it is desirable to use. As the rapid circulation of the water insures equal temperature in all parts, the strains due to unequal expansion cannot occur to deteriorate its strength. The construction of the boiler, moreover, is such that, should unequal expansion occur under extraordinary circumstances, no objectionable strain can be caused thereby, ample elasticity being provided for that purpose in the method of construction.

In this boiler, so powerful is the circulation that as long as there is sufficient water to about half fill the tubes, a rapid current flows through the whole boiler; but if the tubes should finally get almost empty, the circulation then ceases and the boiler might burn and give out; by that time, however, it is so nearly empty as to be incapable of harm if ruptured.

Its successful record of over twenty years proves that by the application of correct principles, the use of proper care and good material in construction, a boiler can be made so as to be in fact as well as in name a "safety boiler."



Return Tubular Boiler at the Edison Electric Light Co.'s Works, West Chester, Pa.
Exploded December 17, 1887, killing seven and wounding eight people.




Babcock & Wilcox Boilers, 1,200 H. P., at Cardenas Sugar Refinery, Cuba. 2,200 H. P. in all.

## *THE THEORY OF STEAM MAKING.*

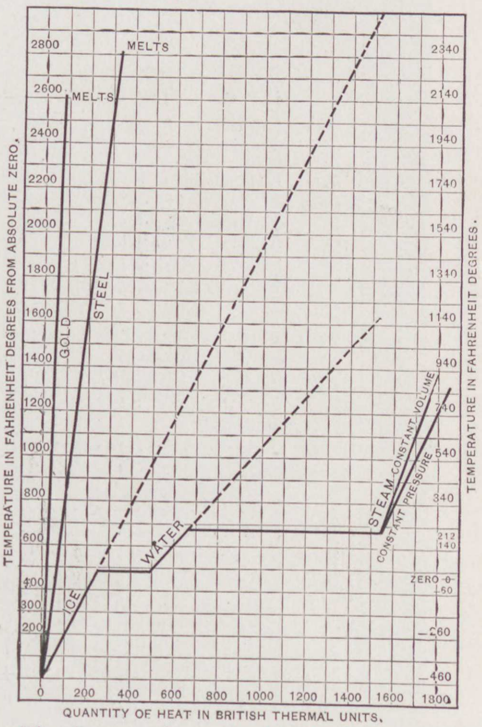
[Extracts from a Lecture delivered by Geo. H. Babcock, at Cornell University, 1887.*]

The chemical compound known as HO exists in three states or conditions — ice, water, and steam; the only difference between these states or conditions is in the presence or absence of a quantity of energy exhibited partly in the form of heat and partly in molecular activity, which, for want of a better name, we are accustomed to call "latent heat;" and to transform it from one state to another we have only to supply or extract heat. For instance, if we take a quantity of ice, say one pound, at absolute zero† and supply heat, the first effect is to raise its temperature until it arrives at a point 492 Fahrenheit degrees above the starting point. Here it stops growing warmer, though we keep on adding heat. It, however, changes from ice to water, and when we have added sufficient heat to have made it, had it remained ice, 283° hotter, or a temperature of 315° by Fahrenheit's thermometer, it has all become water, at the same temperature at which it commenced to change, namely, 492° above absolute zero, or 32° by Fahrenheit's scale. Let us still continue to add heat, and it will now grow warmer again, though at a slower rate — that is, it now takes about double the quantity of heat to raise the pound one degree that it did before — until it reaches a temperature of 212° Fahrenheit, or 672° absolute (assuming that we are at the level of the sea). Here we find another critical point. However much more heat we may apply, the water, as water, at that pressure, cannot be heated any hotter, but changes on the addition of heat to steam; and it is not until we have added heat enough to have raised the temperature of the water 966°, or to 1,178 by Fahrenheit's thermometer (presuming for the moment that its specific heat has not changed since it became water), that it has all become steam, which steam, nevertheless, is at the temperature of 212°, at which the water began to change. Thus over four-fifths of the heat which has been added to the water has disappeared or become insensible in the steam to any of our instruments.

It follows that if we could reduce steam at atmospheric pressure to water, without loss of heat, the heat stored within it would cause the water to be *red hot;* and if we could further change it to a solid, like ice, without loss of heat, the solid would be white hot, or hotter than melted steel — it being assumed, of course, that the specific heat of the water and ice remain normal, or the same as they respectively are at the freezing point.

After steam has been formed, a further addition of heat increases the temperature again at a much faster ratio to the quantity of head added, which ratio also varies according as we maintain a constant pressure or a constant volume; and I am not aware that any other critical point exists where this will cease to be the fact until we arrive at that very high temperature, known as the point of dissociation, at which it becomes resolved into its original gases.

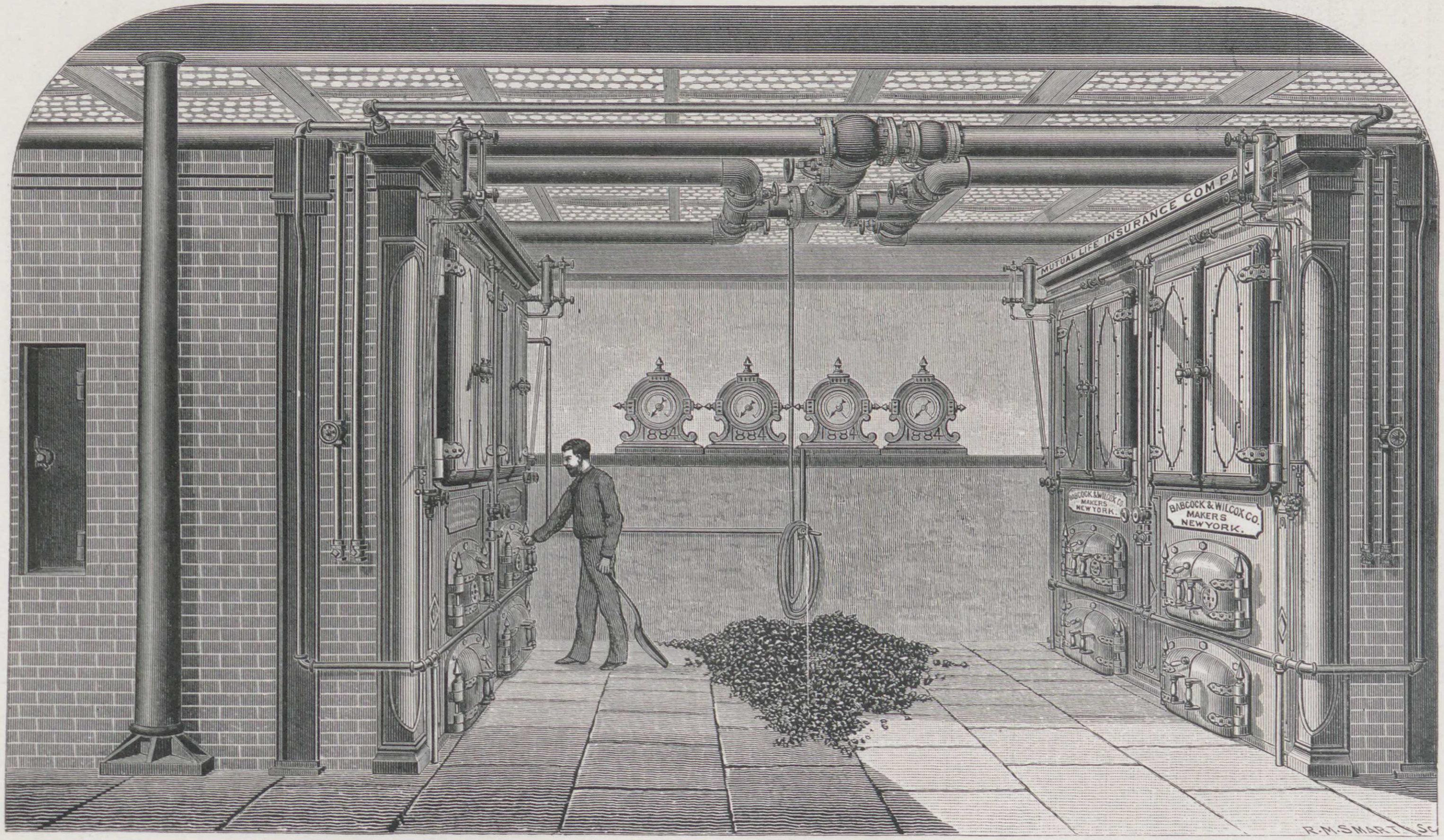
The heat which has been absorbed by one pound of water to convert it into a pound of steam at atmospheric pressure is sufficient to have melted three pounds of steel or thirteen pounds of gold. This has been transformed into something besides heat; stored up to reappear as heat when the process is reversed. That condition is what we are pleased to call latent heat, and in it resides mainly the ability of the steam to do work.




The diagram shows graphically the relation of heat to temperature, the horizontal scale being quantity of heat in British thermal units, and the vertical temperature in Fahrenheit degrees, both reckoned from absolute zero and by the usual scale. The dotted lines for ice and water show the temperature which would have been obtained if the conditions had not changed. The lines

*See *Scientific American* Supplement, 624, 625, Dec. 1887.

†460° below the zero of Fahrenheit. This is the nearest approximation in whole degrees to the latest determinations of the absolute zero of temperature.




Babcock & Wilcox Boilers, 488 H. P., in the New York Mutual Life Insurance Co.'s Building, New York City. Erected 1884, beneath Court Yard.

marked "gold" and "steel" show the relation to heat and temperature and the melting points of these metals. All the inclined lines would be slightly curved if attention had been paid to the changing specific heat, but the curvature would be small. It is worth noting that, with one or two exceptions, the curves of all substances lie between the vertical and that for water. That is to say, that water has a greater capacity for heat than all other substances except two, hydrogen and bromine.

In order to generate steam, then, only two steps are required: First, procure the heat, and, second, transfer it to the water. Now, you have it laid down as an axiom that when a body has been transferred or transformed from one place or state into another, the same work has been done and the same energy expended, whatever may have been the intermediate steps or conditions, or whatever the apparatus. Therefore, when a given quantity of water at a given temperature has been made into steam at a given temperature, a certain definite work has been done, and a certain amount of energy expended, from whatever the heat may have been obtained, or whatever boiler may have been employed for the purpose.

A pound of coal or any other fuel has a definite heat-producing capacity, and is capable of evaporating a definite quantity of water under given conditions. That is the limit beyond which even perfection cannot go, and yet I have known, and doubtless you have heard of, cases where inventors have claimed, and so-called engineers have certified to, much higher results.

The first step in generating steam is in burning the fuel to the best advantage. A pound of carbon will generate 14,500 British thermal units during combustion into carbonic dioxide, and this will be the same, whatever the temperature or the rapidity at which the combustion may take place. If possible, we might oxidize it at as slow a rate as that with which iron rusts or wood rots in the open air, or we might burn it with the rapidity of gunpowder, a ton in a second, yet the total heat generated would be precisely the same. Again, we may keep the temperature down to the lowest point at which combustion can take place, by bringing large bodies of air in contact with it, or otherwise, or we may supply it with just the right quantity of pure oxygen, and burn it at a temperature approaching that of dissociation, and still the heat units given off will be neither more nor less. It follows, therefore, that great latitude in the manner or rapidity of combustion may be taken without affecting the quantity of heat generated.

But in practice it is found that other considerations limit this latitude, and that there are certain conditions necessary in order to get the most *available* heat from a pound of coal. There are three ways, and only three, in which the heat developed by the combustion of coal in a steam boiler furnace may be expended.

*First*, and principally, it should be conveyed to the water in the boiler, and be utilized in the production of steam. To be perfect, a boiler should so utilize all the heat of combustion, but there are no perfect boilers.

*Second.*—A portion of the heat of combustion is conveyed up the chimney in the waste gases. This is in proportion to the weight of the gases, and the difference between their temperature and that of the air and coal before they entered the fire.

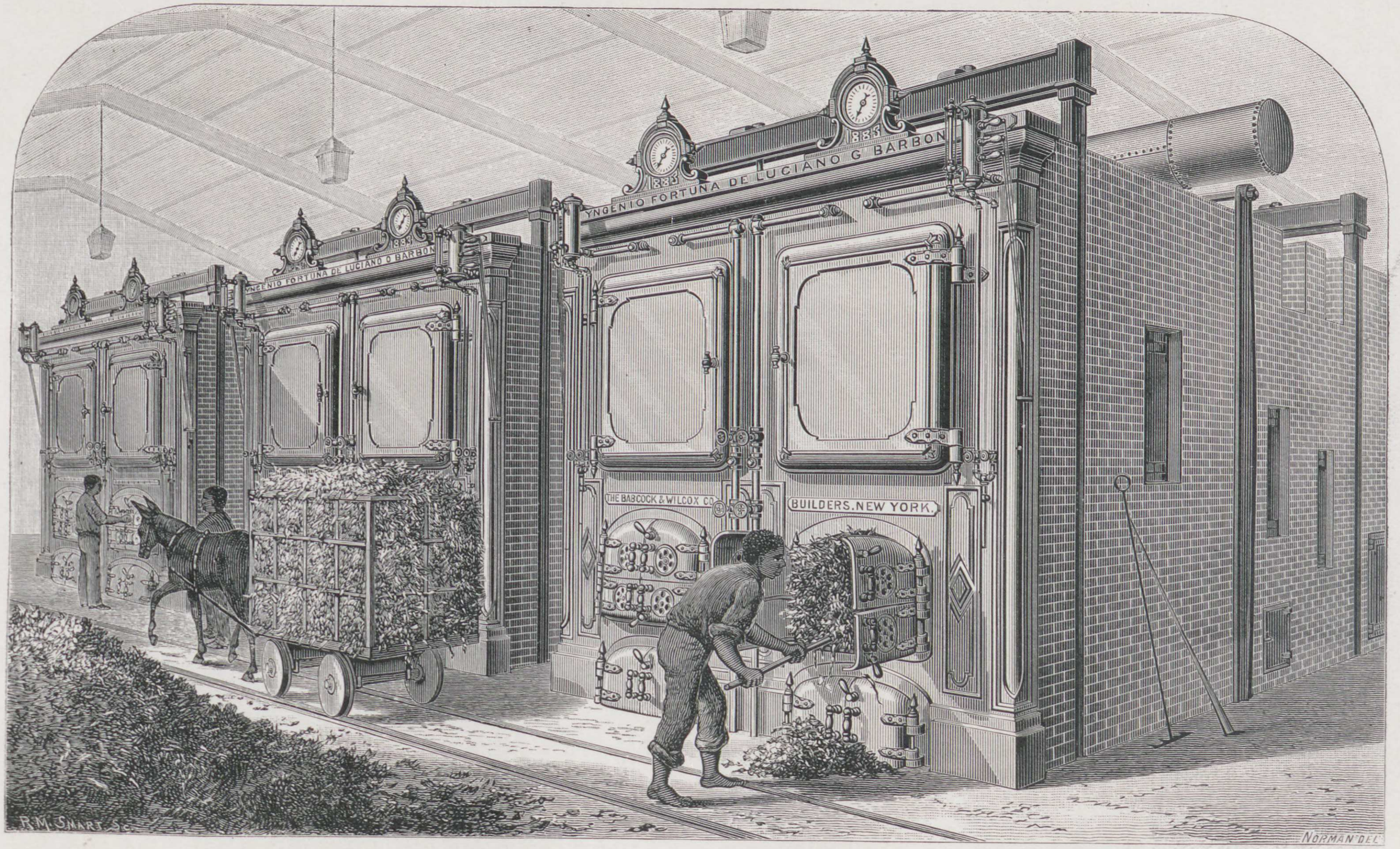
*Third.*—Another portion is dissipated by radiation from the sides of the furnace. In a *stove* the heat is all used in these latter two ways, either it goes off through the chimney or is radiated into the surrounding space. It is one of the principal problems of boiler engineering to render the amount of heat thus lost as small as possible.

The loss from radiation is in proportion to the amount of surface, its nature, its temperature, and the time it is exposed. This loss can be almost entirely eliminated by thick walls and a smooth white or polished surface, but its amount is ordinarily so small that these extraordinary precautions do not pay in practice.

It is evident that the temperature of the escaping gases cannot be brought below that of the absorbing surfaces, while it may be much greater even to that of the fire. This is supposing that all of the escaping gases have passed through the fire. In case air is allowed to leak into the flues, and mingle with the gases after they have left the heating surfaces, the temperature may be brought down to almost any point above that of the atmosphere, but without any reduction in the amount of heat wasted. It is in this way that those low chimney temperatures are sometimes attained which pass for proof of economy with the unobserving. All surplus air admitted to the fire, or to the gases before they leave the heating surfaces, increases the losses.

We are now prepared to see why and how the temperature and the rapidity of combustion in the boiler furnace affect the economy, and that though the amount of heat developed may be the same, the heat available for the generation of steam may be much less with one rate or temperature of combustion than another.

Assuming that there is no air passing up the chimney other than that which has passed through




Babcock & Wilcox Boilers, 624 H. P., at the Ingenio Fortuna de Luciano G. Barbon, Alquizar, Cuba. Erected in 1883, for burning dry bagasse.

the fire, the higher the temperature of the fire and the lower that of the escaping gases the better the economy, for the losses by the chimney gases will bear the same proportion to the heat generated by the combustion as the temperature of those gases bears to the temperature of the the fire. That is to say, if the temperature of the fire is 2,500° and that of the chimney gases 500° above that of the atmosphere, the loss by the chimney will be $\frac{500}{2500} = 20$ per cent. Therefore, as the escaping gases cannot be brought below the temperature of the absorbing surface, which is practically a fixed quantity, the temperature of the fire must be high in order to secure good economy.

The losses by radiation being practically proportioned to the time occupied, the more coal burned in a given furnace in a given time, the less will be the proportionate loss from that cause.

It therefore follows that we should burn our coal rapidly and at a high temperature, to secure the best available economy.

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### THEORY OF HEAT ENGINES.*

In any heat engine it is essential that there should be, 1st, a working fluid; 2d, a source of heat; and 3d, a receptacle for unexpended heat, both of which latter must be external to the working fluid. In its operation there must be a reception of heat by the working fluid, at a certain temperature, a conversion of heat into work, and a discharge of unconverted heat at a lower temperature than that at which it was received. The difference between such higher and lower temperatures is called the "range of temperatures," and the engine is called a "perfect engine" when the whole heat corresponding to its range of temperature is converted into work. Sadi Carnot, in 1824, seems to have been the first to enunciate the principle, now universally recognized, that the ratio of the maximum mechanical effect in a perfect heat engine to the total heat expended upon it, is a function solely of the two constant temperatures, at which respectively heat is received and rejected, and is independent of the nature of the intermediate agent or working fluid, though at that day the dynamic theory of heat was not known, and Carnot supposed that all the heat received in the boiler, or its equivalent, was transferred to the condenser. Subsequent researches of Joule, Rankine and others, have established the following propositions:

1st. *In any heat engine the maximum useful effect* (expressed in foot pounds or in percentage) *bears the same relation to the total heat expended* (expressed in foot pounds or as unity) *that the range of temperature bears to the absolute temperature at which heat is received.*

2d. *In any heat engine the minimum loss of heat bears the same relation to the total heat expended as the temperature at which the heat is rejected bears to the temperature at which it is received,* both being reckoned from absolute zero, 460° † below the zero of Fahrenheit's scale.

These two propositions, expressed in algebraic formulæ, are:

(1) $U = H \frac{\tau_1 - \tau_2}{\tau_1}$, which, if $H = 1$, becomes the well-known equation $U = \frac{\tau_1 - \tau_2}{\tau_1}$; and,

(2) $L = H \frac{\tau_2}{\tau_1}$ in which also, if $H = 1$, $L = \frac{\tau_2}{\tau_1}$.

But as $L + U = 1$, $\therefore U = 1 - \frac{\tau_2}{\tau_1}$, which is identical with (1) differently written.

At this point we need to divest ourselves of an idea which is common, and which naturally comes from the terms used, that "latent" heat is necessarily wasted heat—or, in other words, that if all the heat received was expended in elevating the temperature, instead of a large share of it going into the "latent" condition, we should be able to turn a larger percentage of it into power. It has been upon this erroneous supposition that most of the searches for substitutes for steam have been based. To show its fallacy, practically, it is only necessary to consider the action of an engine using steam as a gas without expenditure of latent heat, and compare it with the results attained in engines in which the latent heat is expended in the boiler and discharged in the condenser. We will assume that steam be supplied at 100° temperature—1 pound pressure, or 28 inches vacuum nearly—that it be worked through Carnot's cycle between that temperature and 320°—the temperature of saturated steam at 75 pounds gauge pressure. The efficiency of this cycle would be, by above formula, $= \frac{780-560}{780} = .28$. The heat expended per pound of steam would be $220 \times .475 \times 772 = 80{,}674$ foot pounds of energy, of which the engine would utilize 28 per cent., or 22,588 foot pounds. There would, therefore, be required $\frac{1{,}980{,}000}{22{,}588} = 87.6$ pounds steam per hourly horse-power, and that in a perfect engine; but, working within the same limits, in a very imperfect engine, using water with its large latent heat, in actual practice, a horse-power is obtained for from 16 to 18 pounds, or about one-fifth the quantity of fluid. Latent

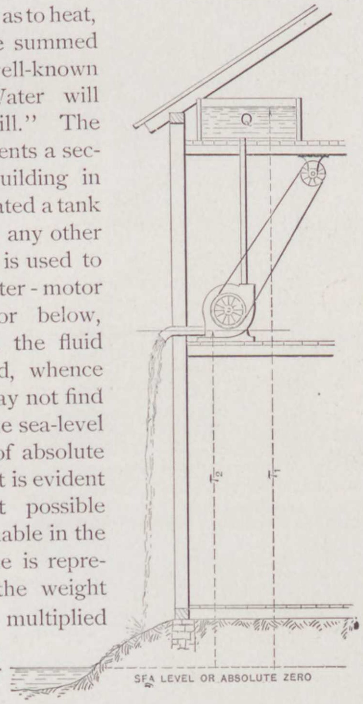
* From "*Substitutes for Steam*," by Geo. H. Babcock, read before the American Society of Mechanical Engineers, May, 1886. *Transactions*, Vol. VII., p. 710.

† See note, p. 13.

Vienna Opera House, Vienna, Austria, lighted by electricity. Power furnished by 1192 H. P. Babcock & Wilcox Boilers.

heat must, therefore, be an efficient source of energy as well as sensible heat. That it is just as much so when working between the same limits of temperature, was demonstrated by Rankine in a series of articles published in the *Engineer* in 1857. And, in fact, it may be said there would be no available energy if there was no latent or specific heat.

We may, perhaps, understand this point a little better by means of an illustration suggested by Carnot, which, though based upon the theory of the materiality of heat, is still just as true under the correct theory. In fact, the second law of thermo-dynamics is equally applicable to a ponderable body as to heat, and may be summed up in the well-known adage, "Water will not run up hill." The figure represents a section of a building in which is situated a tank of water, or any other fluid, which is used to drive a water-motor upon a floor below, after which the fluid is discharged, whence it may or may not find its way to the sea-level — the line of absolute zero. Now it is evident the greatest possible effect obtainable in the motor-engine is represented by the weight of fluid, $Q$, multiplied by its fall to the point of discharge.




The height of the surface of the tank above sea-level is $\tau_1$, and the height of its discharge from same datum-line is $\tau_2$, while its fall is $\tau_1 - \tau_2$, and the greatest efficiency of the motor is expressed by $U = Q\,(\tau_1 - \tau_2)$. But the total energy of the fluid is represented by $Q\,\tau_1$, and the efficiency of the motor expressed in terms of total energy is:

$$U = \frac{Q\,(\tau_1 - \tau_2)}{Q\,\tau_1} = \frac{\tau_1 - \tau_2}{\tau_1}.$$

It is evident that the same law holds good whatever be the character of the fluid in the tank.

Now, the quantity $Q$, — which may represent the latent heat, while the height, $\tau_1$, represents temperature — may be greater or less with the same height. If $Q = 0$, then there would be no available energy, for there would have been none expended. It will also be seen that if in the supposed steam-engine above calculated, 0 be substituted for .475, the specific heat of the steam, there would be no energy in the engine.

From the mere inspection of the above formulæ, in view of this illustration, it is readily seen:

1st. That the useful effect can only equal the total heat expended when the temperature at which it is rejected is absolute zero, in which case it matters not at what temperature the heat may be received.

2d. That with a given minimum temperature, the higher the maximum temperature the greater will be the proportion of total heat converted into useful work.

3. That it is of greater importance to lower the temperature at which heat is rejected than to raise that at which it is received.

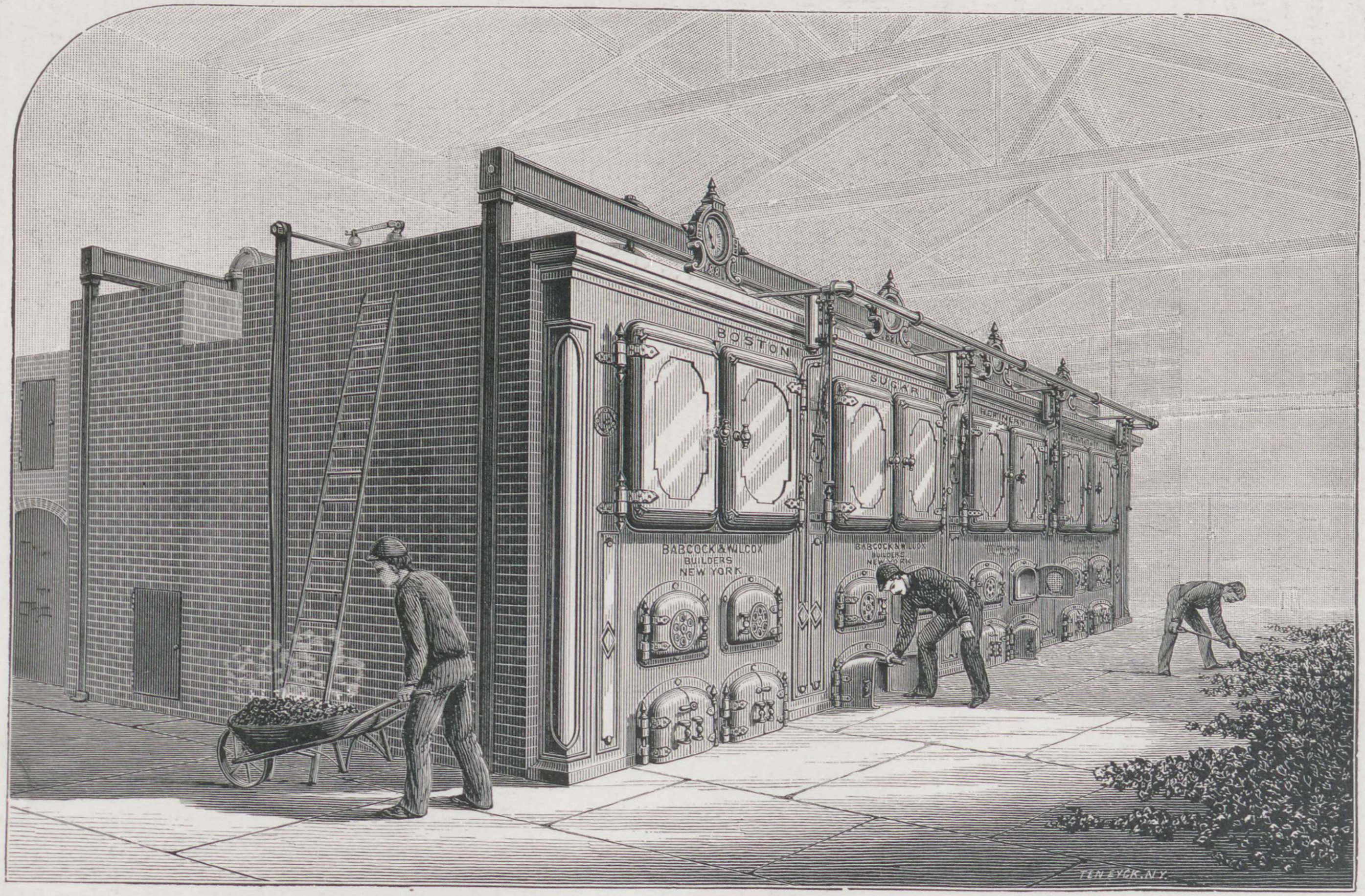
There are, however, practical limits to these several values:

1st. The temperature of rejection cannot be carried below that of the substance into which it is rejected — in practice it must be several degrees above it — and is independent of the fluid employed. As there is, in practice, nothing available colder than air or water, $\tau_2$ cannot easily be less than 100° Fahr., 560° absolute.

2d. The temperature of reception cannot be greater than the highest temperature of combustion, nor greater than the surfaces of the piston and cylinder will stand; nor greater than will produce in the given fluid the highest allowable pressure.

3d. The highest pressure is limited by the strength of the mechanism and safety of its operation, and is also independent of the fluid. As all fluids, except mercury and turpentine, attain this limit of pressure before the limit of temperature, the pressure is the practical limiting condition in this direction.

Obviously, then, as the limits of lowest available temperature and of highest practical pressure are the same for all vapors, it becomes evident that the fluid having the highest temperature at the limit of pressure, other things being equal, has the advantage, theoretically, in possible economy. Of all available liquids, water fulfils this condition best, and therefore it is useless to search for another vapor as a substitute for steam, unless it can be shown that the losses incidental to the use of the latter are necessarily enough greater than those incidental to some other fluid, to more than counterbalance this advantage. That there are such compensating advantages is not probable, and they would, indeed, need to be very great to offset the cost of fluid, water being free of cost in nearly all situations.

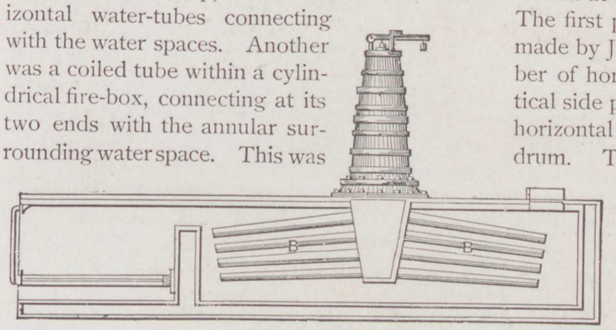



Babcock & Wilcox Boilers at Boston Sugar Refinery, East Boston, Mass. 1000 H. P. Erected 1880.

Showing Style of Fronts for continuous batteries of boilers.

## BRIEF HISTORY OF WATER-TUBE BOILERS.*

Water-tube boilers are not new. From the earliest days of the steam engine, there have been those who recognized their advantages. The first water-tube boiler recorded was made by a contemporary of Watt, William Blakey, in 1766. He arranged several tubes in a furnace, alternately inclined at opposite angles, and connected at their contiguous ends by smaller pipes. But the first successful user of such boilers was James Rumsay, an American inventor, celebrated for his early experiments in steam navigation, and who may be truly classed as the originator of the water-tube boiler, as now known. In 1788 he patented, in England, several forms of boilers, among them, one having a fire-box with flat water-sides and top, across which were horizontal water-tubes connecting with the water spaces. Another was a coiled tube within a cylindrical fire-box, connecting at its two ends with the annular surrounding water space. This was the first of the "coil boilers." Another form in the same patent was the vertical tubular boiler, as at present made.



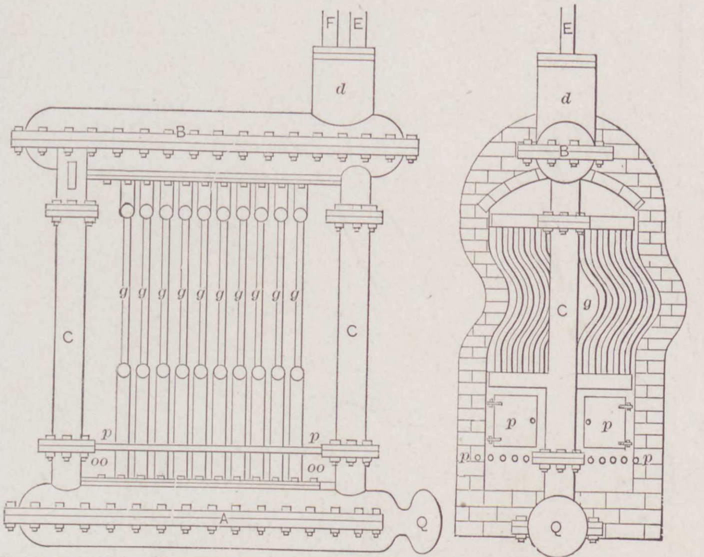
Stephen, 1805.

The first boiler made of a combination of small tubes, connected at one end to a reservoir, was the invention of another American, John Cox Stephens, in 1805.

This boiler was actually employed to drive a steamboat on the Hudson River, but like all the "porcupine" boilers of which it was the first, it did not have the elements of a continued success.

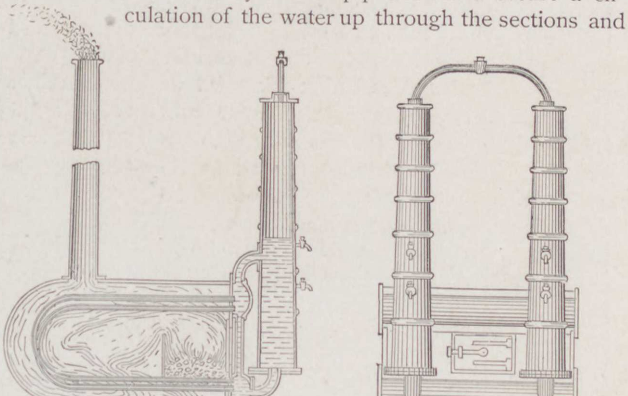
* See discussion by Geo. H. Babcock, of Sterling's paper on "Water-tube and Shell Boilers," in *Trans. Am. Society of Mechanical Engineers*, Vol., VI., p. 601.

About the same time, Wolf, the inventor of compound engines, made a boiler of large horizontal tubes, laid across the furnace and connected at the ends to a longitudinal drum above.



Joseph Eve, 1825.

The first purely sectional water-tube boiler was made by Julius Griffith, in 1821, who used a number of horizontal water-tubes connected to vertical side pipes, which were in turn connected to horizontal gathering pipes, and these to a steam drum. The first sectional water-tube boiler, with a well-defined circulation, was made by Joseph Eve, in 1825. His sections were composed of small tubes slightly double curved but practically vertical, fixed in horizontal headers, which were in turn connected to a steam space above and water space below formed of larger pipes, and connected by outside pipes so as to secure a circulation of the water up through the sections and



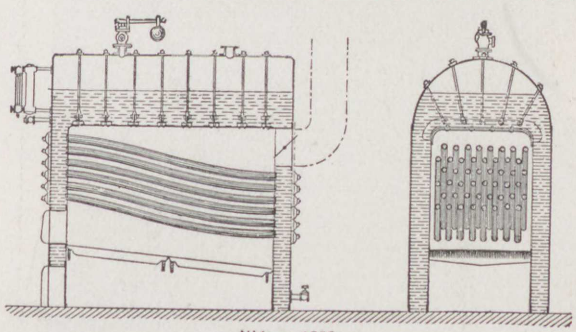
Gurney, 1826.

Babcock & Wilcox Boilers at Pennsylvania Steel Co.'s Works, Sparrows Point, Md. 4,000 H. P. in Process of erection, 1888.

down the external pipes. The same year John M'Curdy, of New York, made a "Duplex Steam Generator," of "tubes of wrought or cast-iron or other material" arranged in several horizontal rows, connected together alternately front and rear by return bends. In 1826, Goldsworthy Gurney made a number of boilers which he used on his steam carriages, consisting of a series of small tubes bent into the shape of a U laid edgewise, which connected top and bottom with large horizontal pipes. These latter were united by vertical pipes to permit of circulation, and also connected to a vertical cylinder forming the steam and water reservoirs. In 1828, Paul Steenstrup made the first shell boiler with vertical water-tubes in the large flues, similar to what is known as the "Martin," and suggesting the "Galloway."

The first water-tube boiler having fire-tubes within water-tubes was made in 1830, by Summers & Ogle. Horizontal connections at top and bottom, had a series of vertical water-tubes connecting them, through which were fire tubes extending through the horizontal connections, with nuts upon them to bind the parts together and make the joints, suggesting some recent patents.

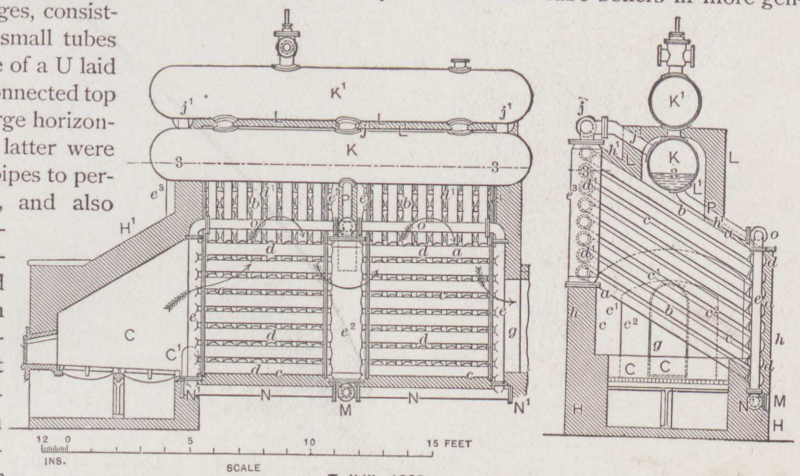
The first person to use *inclined* water-tubes connecting water spaces front and rear with a steam space above, was Stephen Wilcox in 1856, and the first to make such inclined tubes into a sectional form was one Twibill in 1865. He used wrought-iron tubes connected front and rear by intermediate connections with stand pipes, which carried the steam to a horizontal cross-drum at the top, the entrained water being carried back to the rear.



Wilcox, 1856.

Time would fail to tell of Clark, and Perkins, and Moore (English), and McDowell, and Alban, and Craddock, and the host of others who have tried to make water-tube boilers, and have not made practical successes, because of the difficulties of the problem.

Why are not water-tube boilers in more general use, compared with shell boilers? is asked. Because they require a high class of engineering to make them successful. The plain cylinder is an easy thing to make. It requires little skill to rivet sheets into a cylinder, build a fire under it and call it a boiler; and because it is easy and any one can make such a boiler — because it requires no special engineering — they have been made, and are still made, to a very large extent. The water-tube boiler, on the other hand, requires much more skill in order to make it successful. This is proven by the great number of failures in attempts to make water-tube boilers, some of which are referred to in the paper under discussion.




Twibill, 1865.

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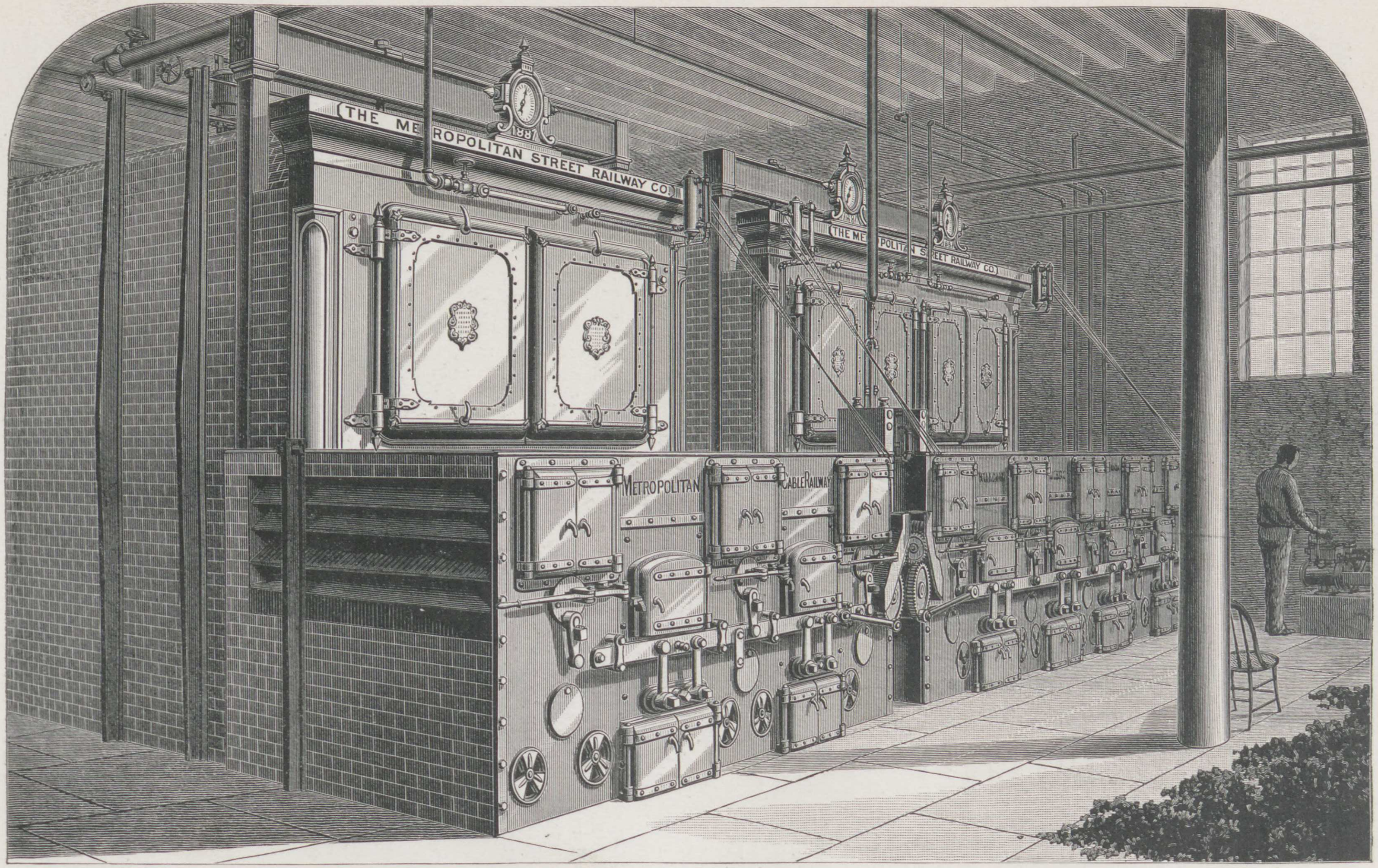
The Babcock & Wilcox Water-tube Boiler has grown out of that of Stephen Wilcox, of 1856, so that it may be said to date back to that year, though the first joint patent was eleven years later. Dr. Alban had stated the axiom that "all boilers should be so constructed that their explosion should not be dangerous," and Harrison had put such boilers into use, made of cast-iron globes, but the Babcock & Wilcox boiler of 1867 was the first to combine the sectional construction with a free circulation of the water in one continuous round. This construction, known all over the world as the Babcock & Wilcox type, is now almost universally acknowledged to be the best possible for safety, economy, and durability.



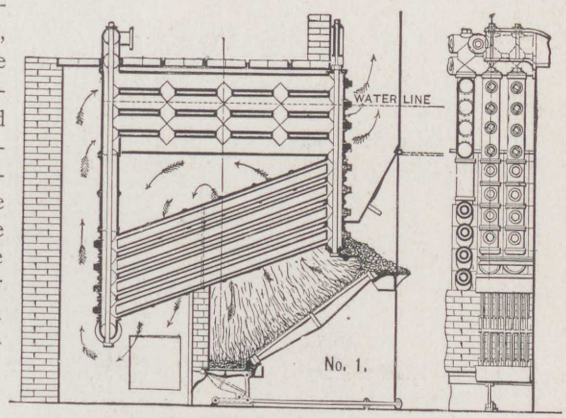

Babcock & Wilcox Boilers, in connection with Murphy Furnaces, at 5th St. Station, Metropolitan Street Railway Co., Kansas City, Mo. 600 H. P. Erected 1886-7

## EVOLUTION OF THE BABCOCK & WILCOX WATER-TUBE BOILER.

We learn quite as much from the record of failures as through the results of success. When a thing has been once fairly tried and found to be impracticable, or imperfect, the knowlege of that trial forms a beacon light to warn those who come after not to run upon the same rock. Still it is an almost every day occurrence that a device or construction which has been tried and found wanting if not worthless, is again brought up as a great improvement upon other things which have proven by their survival to have been the "fittest." This is particularly the case when a person or firm, have, by long and expensive experience, succeeded in supplying a felt want, and developed a business which promises to pay them in the end for their trouble and outlay; immediately a class of persons, who desire to reap where they have not sown, rush into the market with something similar, and, generally, with some idea which the successful party had tried and discarded, claiming it as an "improvement," seek to entice customers, who in the end find they have spent their money for that which satisfieth not. And not infrequently steam users, having been inadvertently induced to experiment on the ill-digested plans of some unfledged inventor, unjustly condemn the whole class, and resolve henceforth to stick to the things their fathers approved.

The success of the Babcock & Wilcox boiler is due to twenty-three years constant adherence to one line of research, experimenting and practical working. In that time they have tried many plans which have not proven to be practicable, and were in fact in whole or in part, failures. During these twenty-three years they have seen *more than thirty* water-tube, or sectional boilers put upon the market, by other parties, some of which attained to some distinction and sale, but all of which have completely disappeared, leaving scarce a trace behind, save in the memories of their victims. The following list—not complete—will serve to bring the names of some to memories which can recall twenty years or less: Dimpfel, Howard, Griffith & Wundrum, Dinsmore, Miller "Fire-box," Miller "American," Miller "Internal Tube," Miller "Inclined Tube," Phleger, Weigand, the Lady Verner, the Allen, the Kelly, the Anderson, the Rogers & Black, the Eclipse or Kilgore; the Moore, the Baker & Smith, the Renshaw, the Shackleton, the "Duplex," the Pond & Bradford, the Whittingham, the Bee, the Hazleton or "Common Sense," the Reynolds, the Suplee or Luder, the Babbitt, the Reed, the Smith, the Standard, &c.

It is with the object of protecting our customers and friends from disappointment and loss through purchasing such discarded ideas, that we publish the following illustrations of experiments made by us in the development of our present boiler, the value and success of which is evidenced by the fact that the largest and most discriminate buyers continue to purchase them after years of practical experience with their workings. All the constructions herein shown, and very many others, are covered by patents belonging to the Babcock & Wilcox Company.

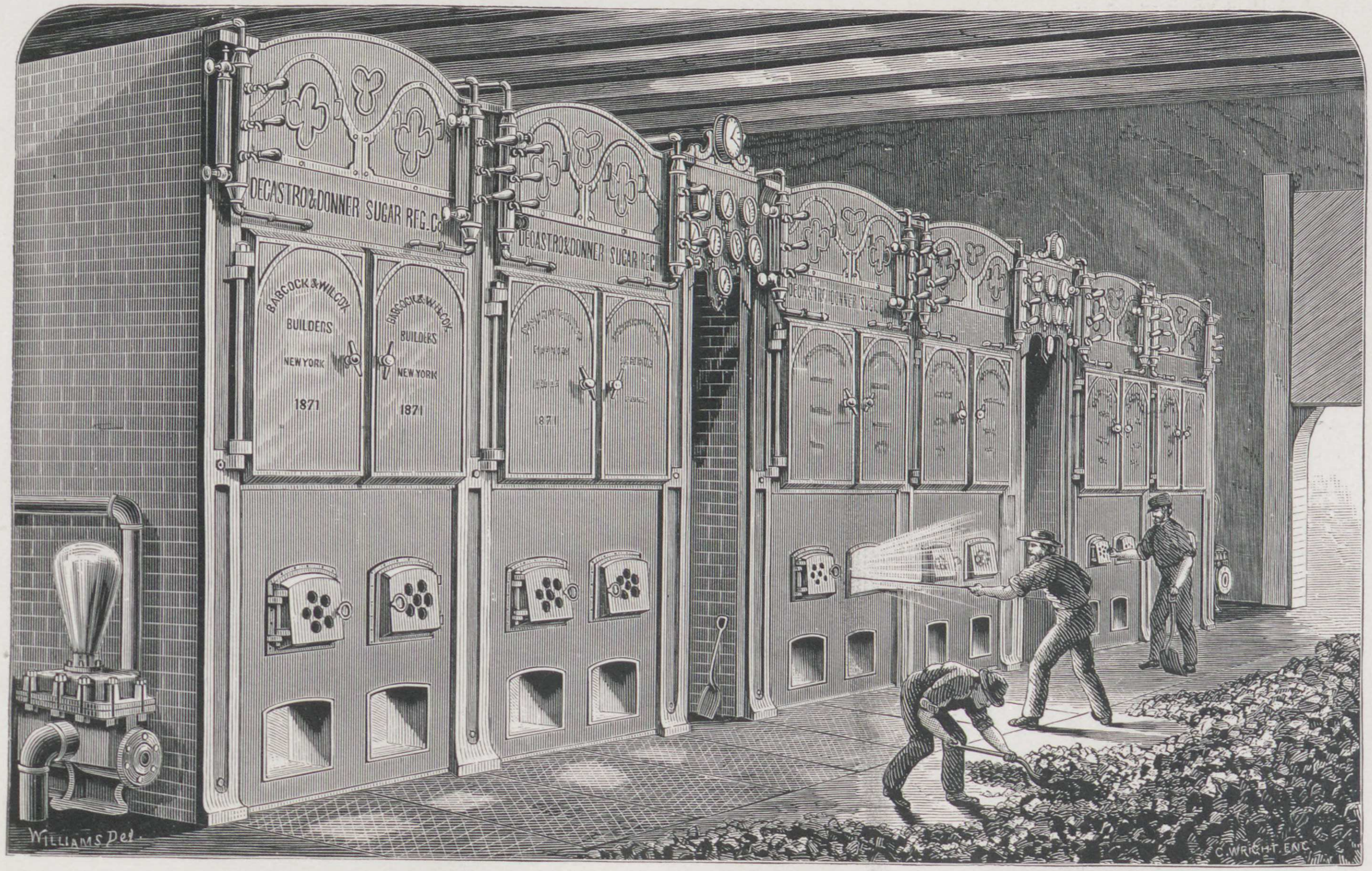



No. 1.—The original Babcock & Wilcox boiler, patented in 1867. The main idea was safety; to it all other elements were sacrificed wherever they conflicted. The boiler consisted of a nest of horizontal tubes serving as steam and water reservoir, placed above and connected at each end by bolted joints, to a nest of inclined heating tubes filled with water. Internal tubes were placed in these latter to assist circulation. The tubes were placed in vertical rows above each other, each vertical row and its connecting end forming a single casting. Hand holes were placed at the end of each tube for cleaning.

No. 2.—The internal circulation tubes were found to hinder, rather than help, circulation and were left out.

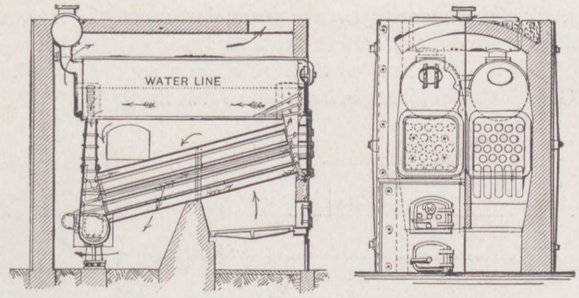
Nos. 1 and 2 were found to be faulty in both material and design, cast metal proving itself unfit for heating surfaces placed directly over the fire, cracking as soon as they became coated with scale.

No. 3.—Wrought-iron tubes were substituted for the cast-iron heating tubes, the ends being brightened and laid in the mould, the headers cast on.



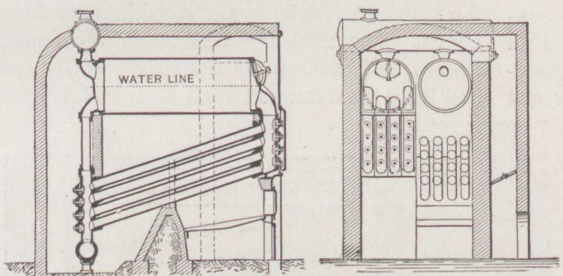

Babcock & Wilcox Boilers, at DeCastro & Donner's Sugar Refining Co.'s Refinery, foot of South 9th St., Brooklyn, E. D., N. Y. Erected 1871. 1st and 2d Orders. 900 H. P.
Facing these have been added 150 H. P., 1877; 300 H. P., 1881; 385 H. P., 1888. Total, 1735 H. P.

The steam and water capacity was insufficient to secure regularity of action, having no reserve to draw upon when irreguarly fed or fired. The attempt to dry the wet steam, produced by superheating in the nest of tubes which formed the steam space, was found to be impracticable; the steam delivered was either wet, dry or superheated, according to the demands upon the boiler. Sediment was found to lodge in the lowest point of the boiler at the rear end, and the exposed portion of the castings cracked off when subjected to the furnace heat.




No. 5.

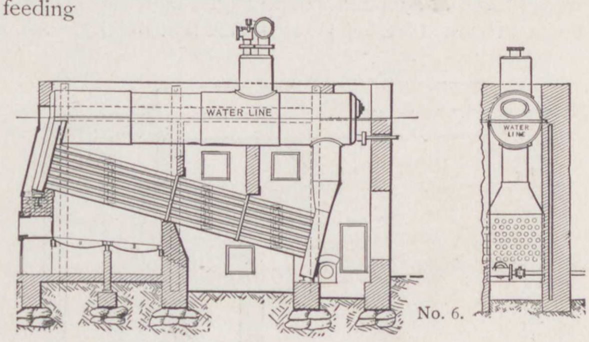
No. 4.—A plain cylinder carrying the water line at the center, leaving the upper half for steam space, was substituted for the nest of tubes. The sections were made as in No. 3, and a mud-drum added to the rear end of the sections at the lowest point farthest removed from the fire; the gases passed off to the stack at one side without coming in contact with it. Dry steam was secured by the great increase of separating surface and steam space, and the added water capacity furnished a storage for heat to tide over the irregularities of feeding and firing. By the addition of the drum it lost a little in *safety*, but, on the other hand, it became a serviceable and practical design, retaining all the elements of safety except small diameter of steam reservoir, which was never large, and was removed from the direct action of the fire, but difficulties were encountered in securing reliable joints between the wrought-iron tubes and the cast-iron headers.




No. 4.

No. 5.—Wrought-iron water legs were substituted for the cast-iron headers; the tubes were expanded into the inside sheets, and a large cover placed opposite the front end of the tubes for cleaning. The staggered position of tubes, one above the other, was introduced and found to be more efficient and economical than where the tubes were placed in vertical rows. In other respects it was similar to No. 4, but it had further lost the important element of safety, the sectional construction, and a very objectionable feature, that of flat stayed surfaces, had been introduced. The large doors for access to the tubes were also a cause of weakness. A large plant of these boilers was placed in the Calvert Sugar Refinery, Baltimore, and did good work, but they were never duplicated.

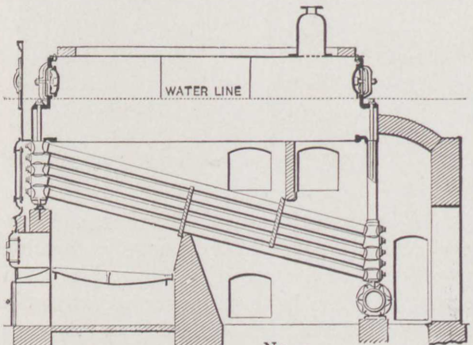
No. 6.—A modification of No. 5, in which longer tubes were used with three passages of the gases across them, to obtain better economy. Also some of the stayed surfaces were omitted and hand holes were substituted for the large doors. A number of this type were built, but their excessive first cost, lack of adjustability of the structure under varying temperatures, and the inconvenience of transporting the last two styles together with the difficulty of erecting large plants without enormous cost for brick-work, as well as the "commerical engineering" of several competing firms then in the market, who made a selling point of their ability to add power to any given boiler after it had once been erected, led to:




No. 6.

No. 7.—In this separate T heads were screwed on to the end of each inclined tube; their faces milled off, the tubes placed on top of each other, metal to metal, and bolted together by long bolts passed through each vertical section of tube heads, and the connecting boxes on the heads of the drum. A large number of these boilers were put into use, some of which are still at work after sixteen to twenty years, but most of them have been altered to the later type.

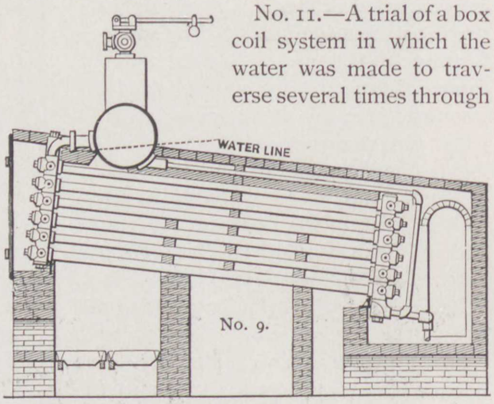
Nos. 8 and 9 are what were known as the Griffith & Wundrum boilers, afterwards merged




No. 7.

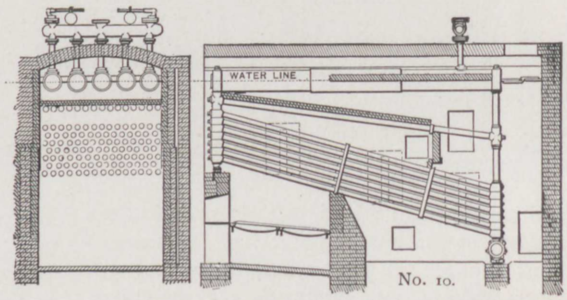
into the Babcock & Wilcox. In these, experiments were made on four passages of the gases across the tubes, and the downward circulation of the water at the rear end of the boiler was carried to the bottom row of tubes. In No. 9, an attempt was made to reduce the amount of steam and water capacity, increase the safety and reduce the cost. A drum at right angle to the line of tubes was tried, but found to be insufficient to secure dry steam or regularity of action. The changes were not found to possess any advantages.

No. 10.—A move in the same direction. A nest of small horizontal drums, 15 in. in diameter were used instead of the single drums of larger diameter; and a set of circulation tubes were placed at an intermediate angle, between the main bank of heating tubes and the horizontal tubes which formed the steam reservoir, to return the water carried up by the circulation to the rear end of the heating tubes, allowing the steam only to be delivered into the small drums above. The result was exceedingly wet steam, with no improvement in action over No. 9. The four passages of the gases did not add to the economy in either Nos. 8, 9 or 10.



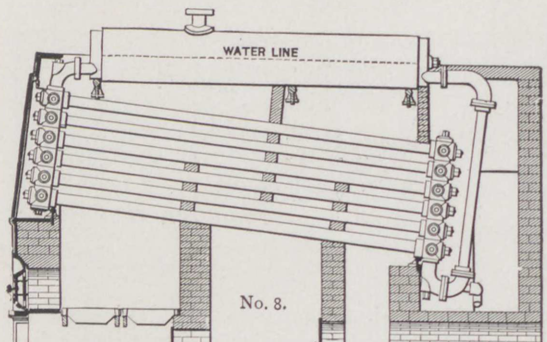

No. 9.

No. 11.—A trial of a box coil system in which the water was made to traverse several times through the furnace before being delivered into the drum above. The tendency was as in all similar boilers, to form steam in the middle of the coil and blow the water out from each end, leaving the tubes practically dry until the steam found an outlet and the water returned. This boiler not only had a defective circulation but a decidedly geyser-like action, and produced wet steam.

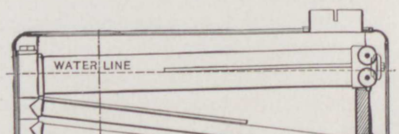



No. 10.

All the above types, with the exception of Nos. 5 and 6, had a large number of bolted joints between their several parts and many of them leaked seriously, from unequal expansion, as soon as the heating surfaces became scaled; enough boilers having been placed at work



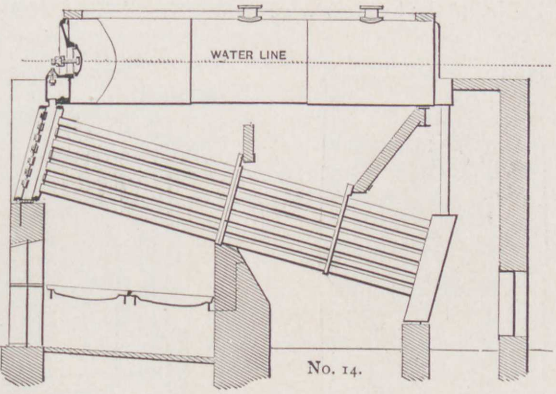

No. 8.




No. 11.

to demonstrate their unreliability in this particular.

No. 12.—An attempt to avoid this difficulty and increase the heating surface in a given space. The tubes were expanded into both sides of wrought-iron boxes, openings being made in them for the admission of water and the exit of steam. Fire-tubes were placed inside these tubes

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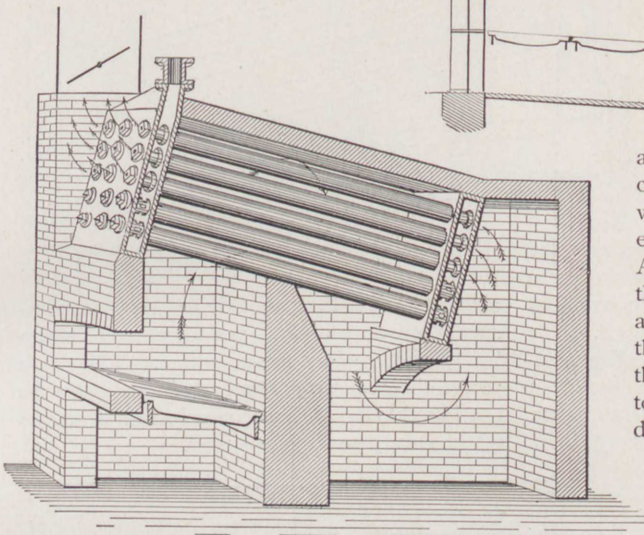


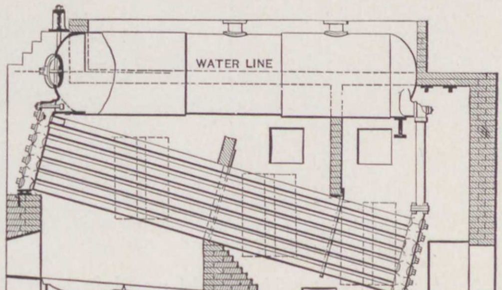
No. 12.

to increase the surface. These were abandoned because they quickly stopped up with scale, and could not be cleaned.

No. 13.—Water boxes formed of cast-iron of the full width and height of the bank of tubes were made of a single casting, which were bolted to the steam water-drum above.

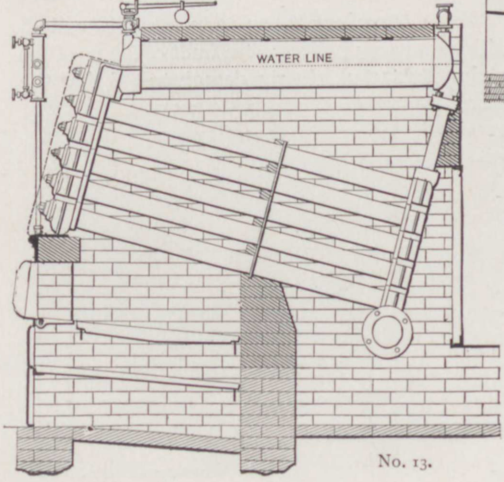
No. 14.—A wrought-iron box was substituted for the cast-iron. In this, stays were necessary and were found, as is always the case, to be an element to be avoided wherever possible. It was, however, an improvement on No. 6. A slanting bridge wall underneath the drum was introduced to throw a larger portion of its surface into the first combustion chamber above the bank of tubes. This was found to be of no special benefit, and difficult to keep in good order.

No. 15.—Each vertical row of tubes was expanded at each end into a continuous header, cast of car wheel metal; the headers having a sinuous form so that



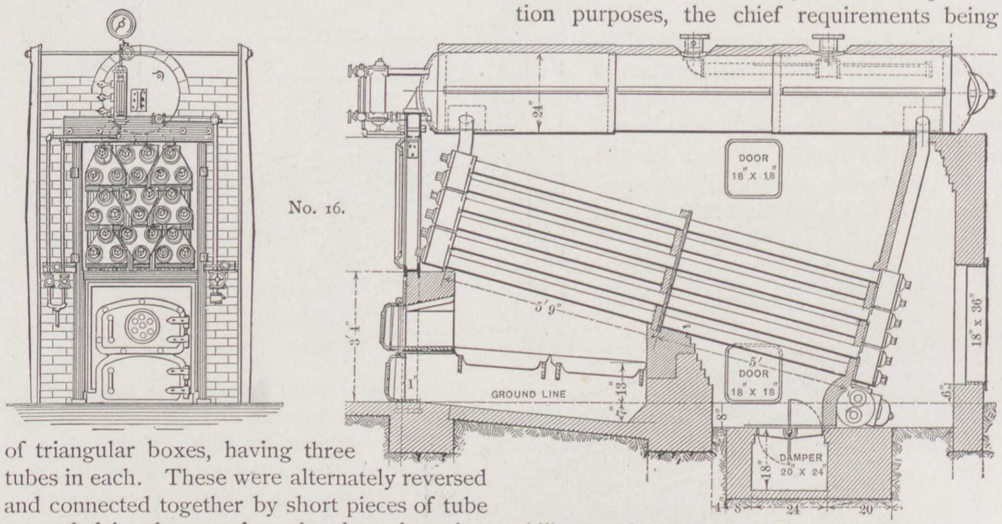

No. 15.

they would lie close together and admit of a staggered position of the tubes in the furnace. This form of header has been found to be the best for all purposes, and has not since been materially changed. The drum was supported by girders resting on the brick-work. Bolted joints were discarded, with the exception of those connecting the headers to the front and rear end of the drum and the bottom of the rear header to the mud-drum. But even these bolted joints were found objectionable and were superseded in subsequent constructions by pieces of tube expanded into bored holes.



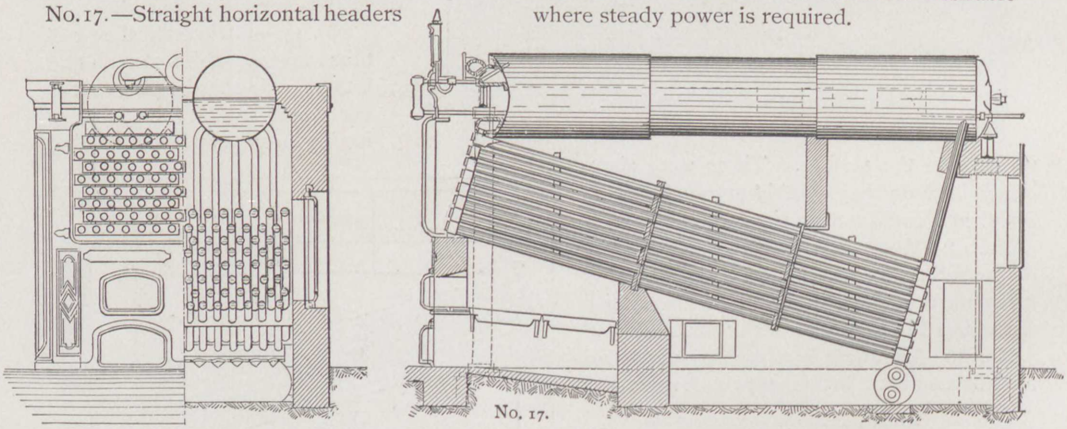

No. 13.

In No. 16 the headers were made in the form of triangular boxes, having three tubes in each. These were alternately reversed and connected together by short pieces of tube expanded in place, and to the drum by tubes bent so as to come normal to the shell. The joints between the headers introduced an element of weakness, and connections to the drum were insufficient to give the adequate circulation.



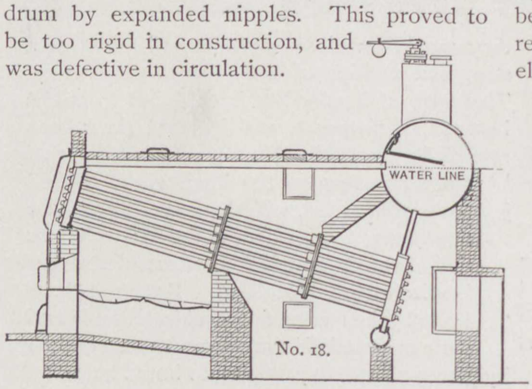
No. 16.

No. 17.—Straight horizontal headers were tried, alternately shifted right and left, to give a staggered position to the tubes. These headers were connected to each other and to the drum by expanded nipples. This proved to be too rigid in construction, and was defective in circulation.


No. 17.

Nos. 18 and 19 were designed for fire protection purposes, the chief requirements being ability to raise steam quickly and hold the pressure; economy of fuel and dryness of steam being of secondary consideration. They both served their *special purpose* admirably, but were not found to be either economical or desirable where steady power is required.

These experiments, as they may be called, although many boilers were built of some of the styles illustrated, clearly demonstrated that the best construction and efficiency required adherence to the following elements:



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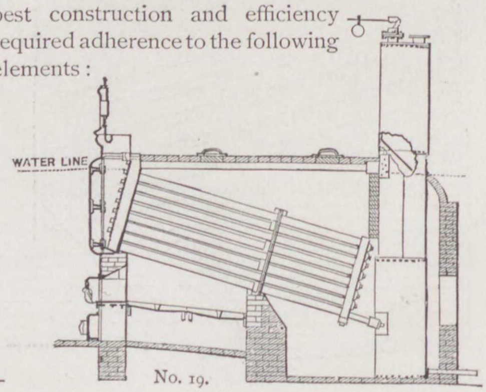
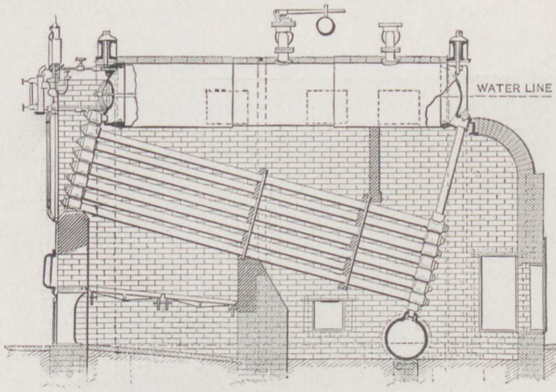


No. 19.

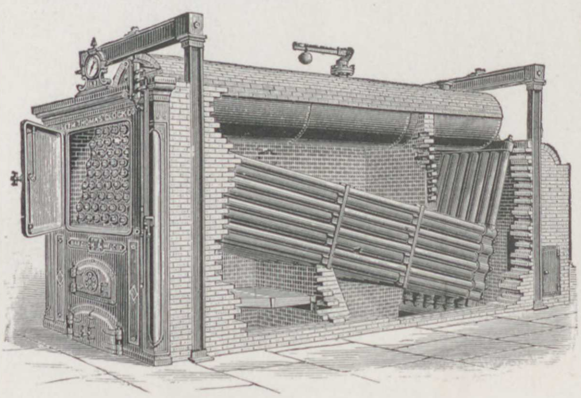
1st. Sinuous headers for each vertical row of tubes. 2d. A separate and independent connection with the drum, both front and rear, for




No. 20.

each such vertical row of tubes. 3d. All joints between the parts of the boiler proper to be made without bolts or screws-threads. 4th. No surfaces to be used which require to be stayed. 5th. The boiler supported independently of the brick-work, so as to be free to expand and contract as it was heated and cooled. 6th. The drums not less than 30 inches in diameter, except for small boilers. 7th. Every part accessible for cleaning and repair.

Having settled upon these points: No. 20 was designed having all these features, together with other improvements in the details of contruction. The general form of construction of No. 15 was adhered to, but short pieces of boiler tube were used as connections between the sections and drum, and mud-drum; their ends being expanded into adjacent parts

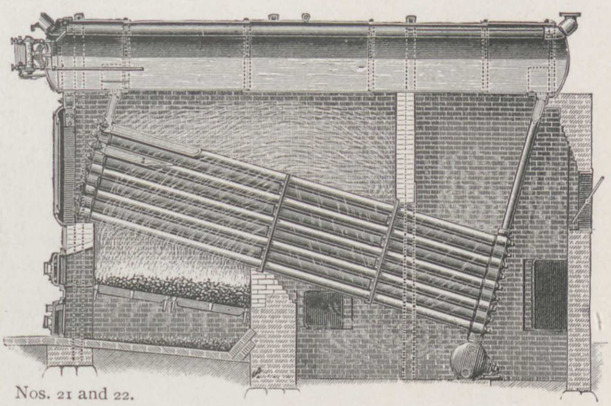


No. 20.

with a Dudgeon expander. This boiler was also suspended entirely independent of the brick-work by means of columns and girders, and the mutally deteriorating strains where one was supported by the other, were avoided.

Hundreds of thousands of horse-power of this style have been built in the last twelve years, giving excellent satisfaction. In fact, most of the boilers referred to in this book are of this style. It is still standard, and is known as our "C. I. F." (cast-iron front) style, a fancy cast-iron front being generally used therewith, as shown in the perspective view. Recent investigations have shown that the average cost of upkeep of the boiler proper is *less than five cents per horse-power per annum.*

No. 21 is a construction more popular in Europe, perhaps, where most of our boilers are made in this style. It is known as our "W. I. F." style, the front usually supplied with it being largely made of wrought-iron. In this boiler, flanged and "bumped" drum-heads of wrought-steel are



Nos. 21 and 22.

used; the drum is longer, and the sections are connected to cross-boxes riveted to its bottom. Where hight is to be saved, the steam is taken out through an internal "dry pipe." In this style also the drum is suspended from columns and girders, though not shown in the figure.

No. 22, the last step in the development of the water-tube boiler, beyond which it seems almost impossible for science and skill to go, consists in making *all parts of the boiler of wrought-steel,* including the sinuous headers, the cross-boxes, and the nozzles on the drum. This was demanded to answer the laws of some of the Continental Nations, and the Babcock & Wilcox Co., have, at the present time, a plant turning out forgings as a regular business, which have been pronounced by the *London Engineer* to be "a perfect triumph of the forgers' art."

Babcock & Wilcox Boiler, 416 H. P., at Pittsburgh Steel Castings Co., Pittsburgh, Pa. Erected 1883. Showing Wrought Iron Front and Flanged Drum-heads.

# DESCRIPTION of the WATER-TUBE BOILER: B & W Co.

### CONSTRUCTION.

This boiler is composed of lap-welded wrought iron tubes, placed in an inclined position and connected with each other, and with a horizontal steam and water drum, by vertical passages at each end, while a mud-drum connects the tubes at the rear and lowest point in the boiler.

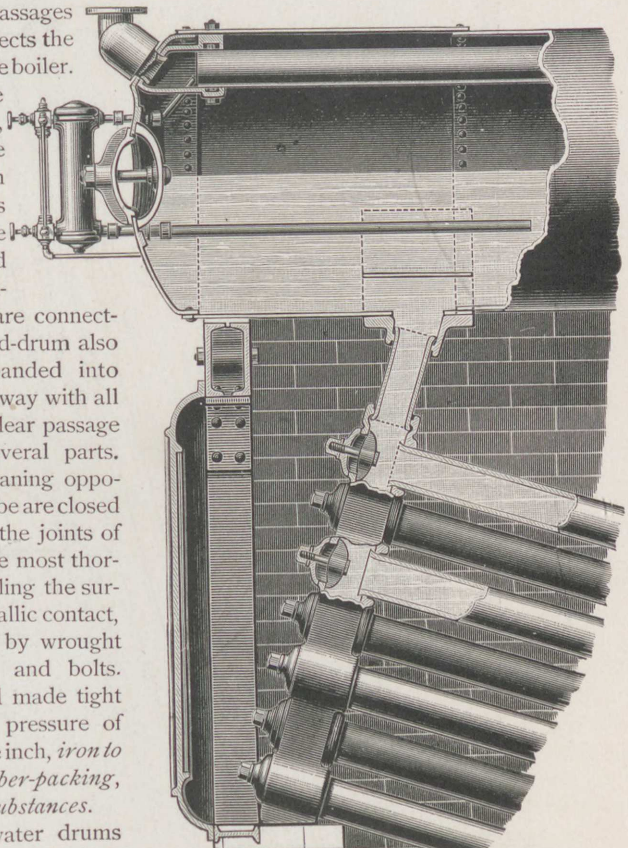
The end connections are in one piece for each vertical row of tubes, and are of such form that the tubes are "staggered" (or so placed that each horizontal row comes over the spaces in the previous row). The holes are accurately sized, made tapering, and the tubes fixed therein by an expander. The sections thus formed are connected with the drum, and with the mud-drum also by short tubes expanded into bored holes, doing away with all bolts, and leaving a clear passage way between the several parts. The openings for cleaning opposite the end of each tube are closed by hand-hole plates, the joints of which are made in the most thorough manner, by milling the surfaces to accurate metallic contact, and are held in place by wrought iron forged clamps and bolts. They are tested and made tight under a hydrostatic pressure of 300 pounds per square inch, *iron to iron, and without rubber-packing, or other perishable substances.*

END VIEW OF HEADER.

The steam and water drums are made of flange iron or steel, of extra thickness, and double riveted. They can be made for any desired working pressure, but are always tested at 150 pounds per square inch unless other-wise ordered. The mud-drums are of cast iron, as the best material to withstand corrosion, and are provided with ample means for cleaning.

### ERECTION.

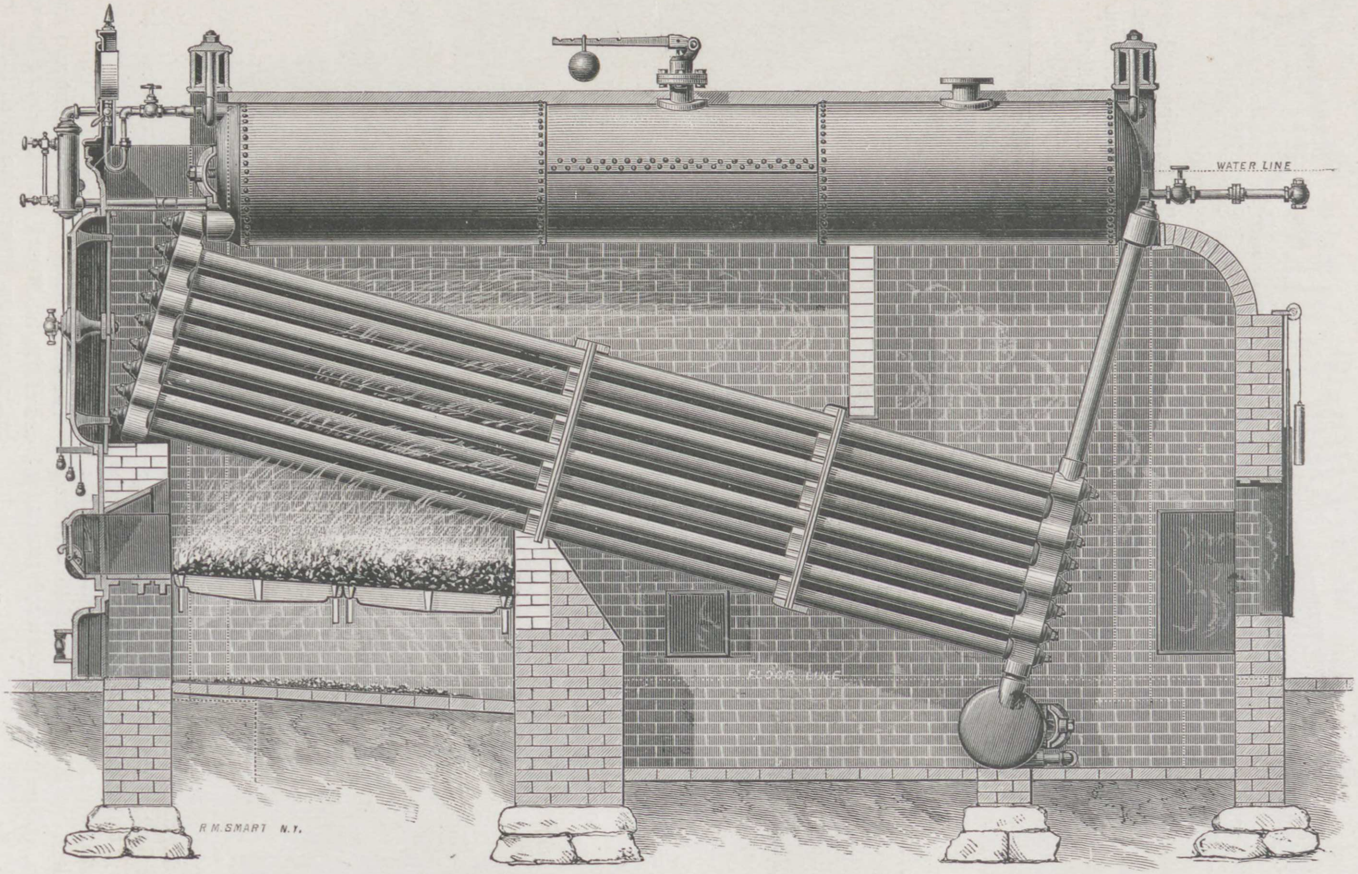
In erecting this boiler, it is suspended entirely independent of the brick-work, from wrought iron girders resting on iron columns. This avoids any straining of the boiler from unequal expansion between it and its enclosing walls, and permits the brick-work to be repaired or removed, if necessary, without in any way disturbing the boiler. All the fixtures are extra heavy and of neat designs.



PARTIAL VERTICAL SECTION.

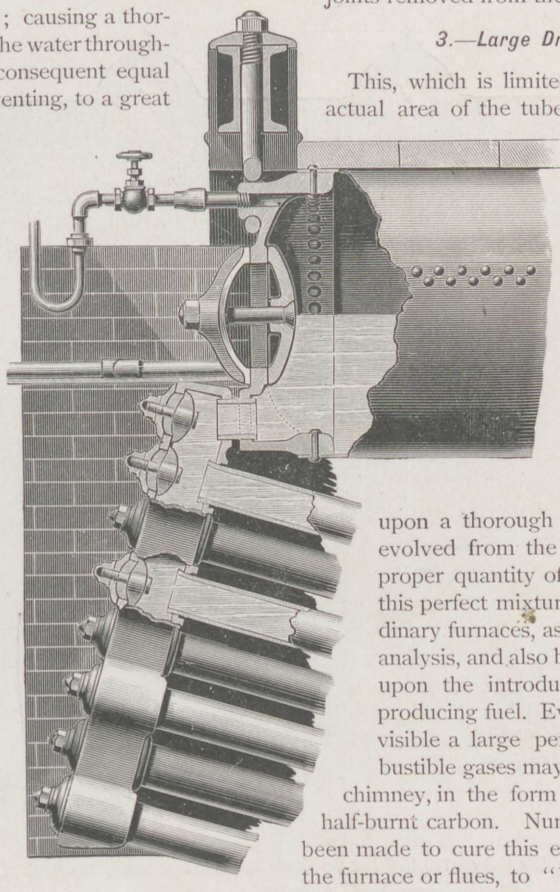
### OPERATION.

The fire is made under the front and higher end of the tubes, and the products of the combustion pass up between the tubes into a combustion chamber under the steam and water-drum; from thence they pass down between the tubes, then once more up through the spaces between the tubes, and off to the chimney. The




Babcock & Wilcox Boiler, 706 H. P., at Raritan Woolen Mills Raritan, N. J. Erected 1878 and 1881. Side Elevation, showing Ornamental Cast Iron Front and Drum-heads.

water inside the tubes, as it is heated, tends to rise towards the higher end, and as it is converted into steam — the mingled column of steam and water being of less specific gravity than the solid water at the back end of the boiler — rises through the vertical passages into the drum above the tubes where the steam separates from the water and the latter flows back to the rear and down again through the tubes in a continuous circulation. As the passages are all large and free, this circulation is very rapid, sweeping away the steam as fast as formed, and supplying its place with water; absorbing the heat of the fire to the best advantage; causing a thorough commingling of the water throughout the boiler and a consequent equal temperature, and preventing, to a great degree, the formation of deposits or incrustations upon the heating surfaces, sweeping them away and depositing them in the mud drum whence they are blown out.



The steam is taken out at the top of the steam-drum near the back end of the boiler after it has thoroughly separated from the water.

#### *ADVANTAGES.*

The following are the prominent advantages which this boiler presents over those of the ordinary construction:

#### *1.—Thin Heating Surface in Furnace.*

The thick plates necessarily used in ordinary boilers, in the furnace, or immediately exposed to the fire, not only hinder the transmission of heat to the water, but admit of overheating, and even burning the side next the fire, with consequent strains, resulting in loss of strength, cracks, and tendency to rupture. This is admittedly the direct cause of most explosions. Water-tubes, however, admit of thin envelopes for the water next the fire, with such ready transmission of heat that even the fiercest fire cannot over-heat or injure the surface, as long as it is covered with water upon the other side.

#### *2.—Joints Removed from the Fire.*

Riveted joints with their consequent double thickness of metal, in parts exposed to the fire, give rise to serious difficulties. Being the weakest parts of the structure, they concentrate upon themselves all strains of unequal expansion, giving rise to frequent leaks, and not rarely to actual rupture. The joints between tubes and tube sheets also give much trouble when exposed to the direct fire, as in locomotive and tubular boilers. These difficulties are wholly overcome by the use of lap-welded water-tubes, with their joints removed from the fire.

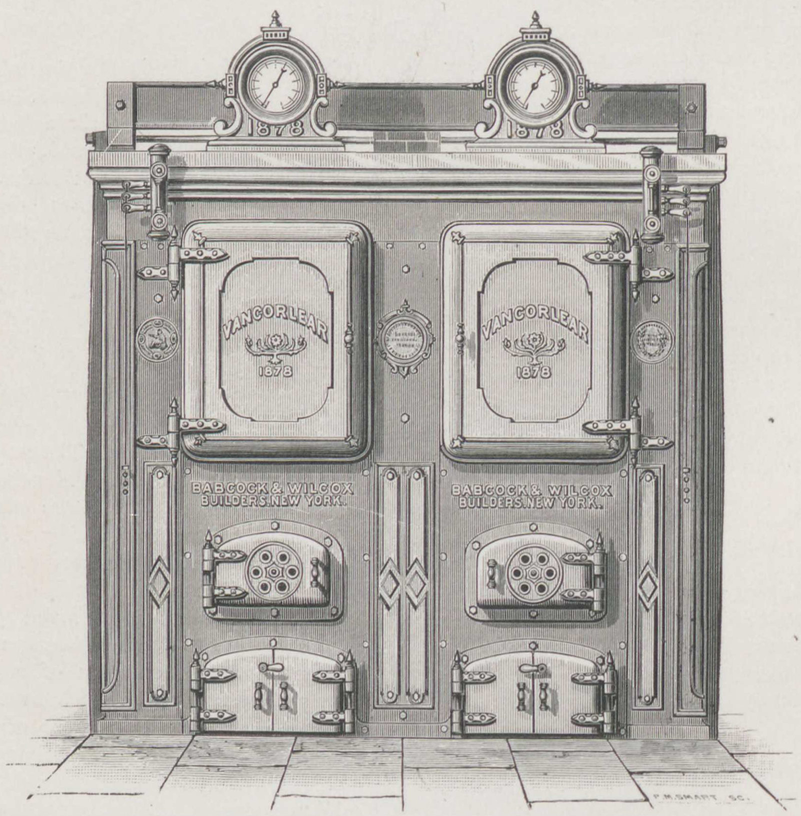
#### *3.—Large Draught Area.*

This, which is limited in fire tubes to the actual area of the tubes, in this boiler is the whole chamber within which the tubes are enclosed, which, with down draft, gives ample time in the passage of the heated gases to the chimney for thorough absorption of their heat.

#### *4.—Complete Combustion.*

The perfection of combustion depends upon a thorough mixture of the gases evolved from the burning of fuel with a proper quantity of atmospheric air; but this perfect mixture rarely occurs in ordinary furnaces, as is proven by chemical analysis, and also by the escape of smoke, upon the introduction of any smoke-producing fuel. Even when smoke is not visible a large percentage of the combustible gases may be escaping into the chimney, in the form of carbonic oxide, or half-burnt carbon. Numerous attempts have been made to cure this evil, by admitting air to the furnace or flues, to "burn the smoke;" but though this may allow so much air to mingle with the smoke as to render it invisible, and at the same time ignite some of the lighter gases, it in reality does little to promote combustion, and the cooling effect of the air more than overbalances all the advantages resulting from the burning gas. The analysis of gases from various furnaces shows almost uniformly an excess of free oxygen, proving that sufficient air is admitted to the furnace, and that a more thorough and perfect *mixing* is needed. Every particle of gas evolved from the fuel should have its equivalent of oxygen, and must find it while hot enough to combine, in order to be effective. In this boiler the currents of gases after leaving the furnace are broken up and thoroughly mingled by passing between the staggered tubes, and have an opportunity to complete their combustion in the triangular chamber between the tubes and drum.

That this does really take place is proved by an analysis by Dr. Behr of the escaping gases from a stack of these boilers at Mattheissen & Weicher's sugar refinery. He made many separate analyses at different times, and in no case was there more than a trace of carbonic oxide, even when there was less than one per cent. of uncombined oxygen.




**Babcock & Wilcox Boilers, 120 H. P., at the Vancorlear Apartment House, New York. Erected 1878.**
Showing style of Ornamental Cast Iron Front.

### *5.—Thorough Absorption of the Heat.*

There are important advantages gained in this respect in consequence of the course of the gases being more nearly at right angles to the heating surface, impinging thereon instead of gliding by in parallel lines as in fire-tube boilers. The currents passing three times across and between the staggered tubes are brought intimately in contact with all parts of the heating surface, rendering it much more efficient than the same area in ordinary tubular boilers.

The experiments of Doctor Alban and of the U. S. Navy have proved that a given surface arranged in that manner is thirty per cent. more efficacious than when in the form of fire tubes as usually employed.

### *6.—Efficient Circulation of Water.*

As all the water in the boiler tends to circulate in one direction, there are no interfering currents, the steam is carried quickly to the surface, all parts of the boiler are kept at a nearly equal temperature, preventing unequal strains, and by the rapid sweeping current the tendency to deposit sediment on the heating surface is materially lessened.

### *7.—Quick Steaming.*

The water being divided in many small streams, in thin envelopes, passing through the hottest part of the furnace, steam may be rapidly raised in starting, and sudden demands upon the boiler may be met by a quickly increased efficiency.

### 8.—Dryness of Steam.

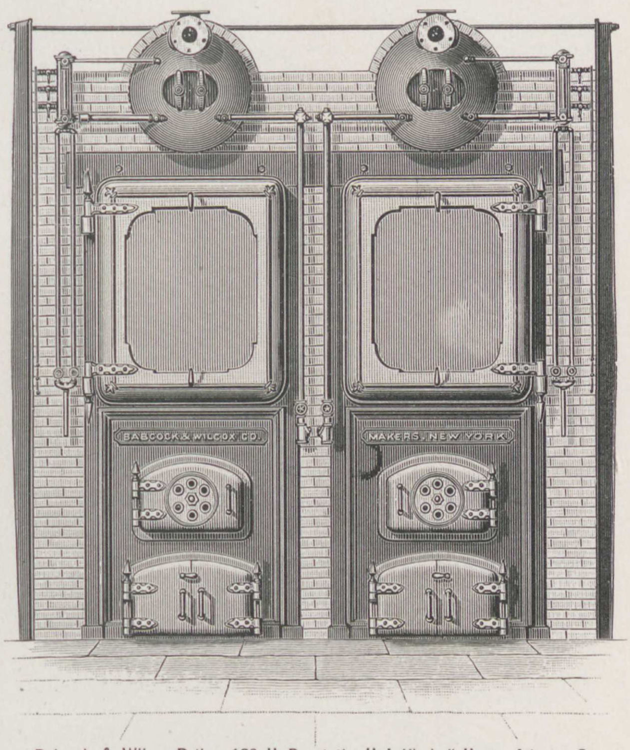
The large disengaging surface of the water in the drum, together with the fact that the steam is delivered at one end and taken out at the other, secures a thorough separation of the steam from the water, even when the boiler is forced to its utmost. Most tubular, locomotive and sectional boilers make wet steam, "priming" or "foaming," as it is called, and in many "super-heating surface" is provided to "dry the steam;" but such surface is always a source of trouble, and is incapable of being graduated to the varying requirements of the steam. No part of a boiler not exposed to water on the one side should be subjected to the heat of the fire upon the other, as the unavoidable unequal expansion necessarily weakens the metal, and is a serious source of danger. Hence a boiler which makes dry steam is to be preferred to one that dries steam which has been made wet.

### 9.—Steadiness of Water Level.

The large area of surface at the water line, and the ample passages for circulation, secure a steadiness of water level not surpassed by any boiler.

### 10.—Freedom of Expansion.

The triangular arrangement of the parts forming a flexible structure allows any member to expand without straining any other, the expanded connections being also amply elastic to meet all necessities of this kind. This is of great importance because the weakening effect of these strains of unequal expansion, between rigidly connected parts, is a prolific cause of explosions in ordinary boilers. The rapid circulation of the water, however, in this boiler, by keeping all parts at the same temperature, prevents to a large extent unequal expansion.




Babcock & Wilcox Boiler, 120 H. P., at the H. I. Kimball House, Atlanta, Ga., Erected 1884. Showing style of Wrought Iron Front.

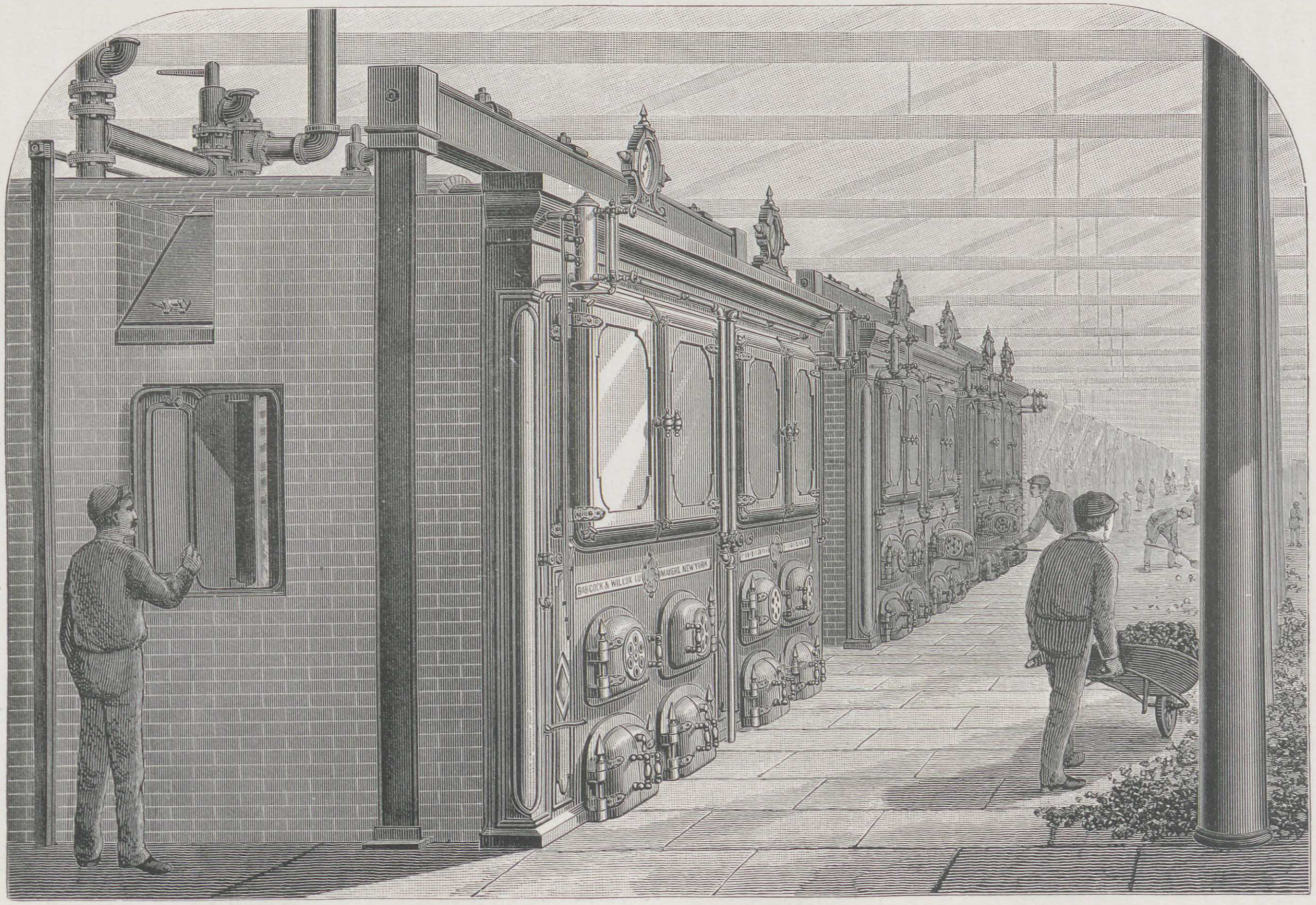
### 11.—Safety from Explosions.

The freedom from unequal expansion avoids the most frequent cause of explosions, while the division of the water into small masses prevents serious destructive effects in case of accidental rupture. The comparatively small diameter of the parts secures, even with thinness of surface, great excess of strength over any pressure which it is desirable to use. So powerful is the circulation of the water, that no part will be uncovered to the fire until the quantity of water in the boiler is so far reduced that if overheating should occur no explosion could result.

### 12.—Capacity.

This is a point of the greatest importance, and upon it depends, in a large measure, the satisfactory performance of any boiler in several particulars. Unless sufficient steam and water capacity is provided there will not be regularity of action; the steam pressure will suddenly rise and as suddenly fall, and the water level will be subject to frequent and rapid changes; and if the steam is drawn suddenly from the boiler, or the boiler crowded, wet steam will result.

Water capacity is of more importance than steam space, owing to the small relative weight of the steam. *Twenty-three* cubic feet of steam, or *one* foot of water space, are required to supply *one horse-power for one minute*, the pressure meantime falling from 80 lbs. to 70 lbs. per square inch. The value of large steam room is therefore generally much overrated, but if it be too small the steam in passing off will sweep the water with it in the form of spray. Too much water space makes slow steaming and waste of fuel in starting. Too much steam space adds to the radiating

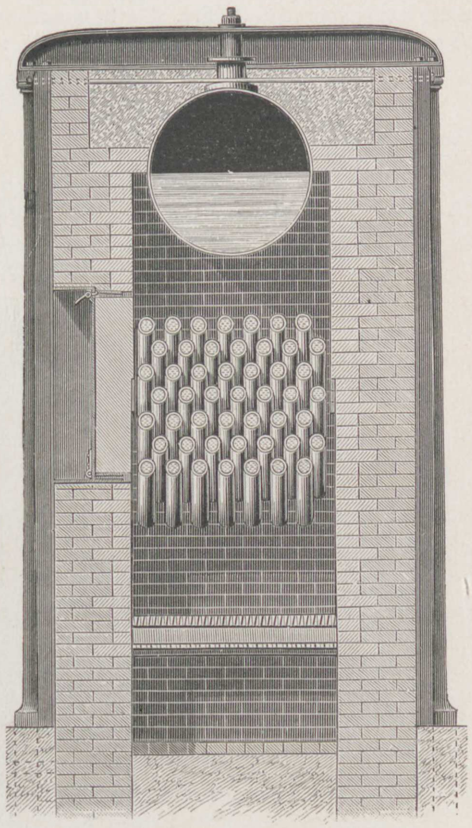


Babcock & Wilcox Boilers at New Orleans Exposition, 1885. Total, 1500 H. P.

surface and increases the losses from that cause. The proportions of this boiler have been adopted after numerous experiments with boilers of varying capacity; and experience has established that this boiler can be driven to the utmost, carrying a steady water level, and steam pressure, and always furnishing dry steam.

The cubical capacity of this boiler, per horse-power, is equal to that of the best practice in tubular boilers of the ordinary construction. The fire surface being of the most effective character, joints, opposite each end of each tube, permit access thereto for cleaning, and a man-hole in the steam and water drum, and hand-holes in mud-drum are provided for the same purpose. All portions of both the exterior and interior surface are fully accessible for cleaning. The occasional use of steam through a blowing pipe attached to a rubber hose operated through doors in the side walls, will keep the tubes free from soot and in condition to receive the heat to the best advantage.


FRONT VIEW.



VERTICAL SECTION.

**Babcock & Wilcox Boiler, at T. A. Edison's Laboratory, Menlo Park, N. J. 75 H. P. Erected 1878.**

Showing style of Fronts for single boilers.

these boilers will, with good fuel and a reasonably economical engine, greatly exceed their rated power, though it is seldom economy to work a boiler above its nominal power. The space occupied by this boiler and setting is equal to about two-thirds that of the same power in tubular boilers

### *13.—Accessibility for Cleaning.*

This is of the greatest importance and is secured to the fullest extent. Hand-holes, with metal

### *14.—Least Loss of Effect from Dust.*

WATER-TUBE.

FIRE-TUBE.

The ordinary fire tube, or flue, receiving the dust from the fire on the interior is quickly covered from one-third to one-half its surface, and in time is completely filled. The water-tube, however, will retain but a limited quantity on its upper side, after which it becomes in a measure self-cleaning.

##### *15.—Durability.*

Besides the important increase of durability due to the absence of deteriorating strains, and of thick plates and joints in the fire, there is no portion of the boiler exposed to the abrasive action which so rapidly destroys the ends of fire tubes, or to the blow-pipe action of the flame upon the crown sheet, bridge walls and tube sheets, which are so destructive frequently to ordinary, particularly locomotive boilers. Neither is there any portion of the surface above the water level exposed to the fire. For these reasons these boilers are durable, and less liable to repairs, than other boilers under the same circumstances, and having the same care.

##### *16.—Ease of Transportation.*

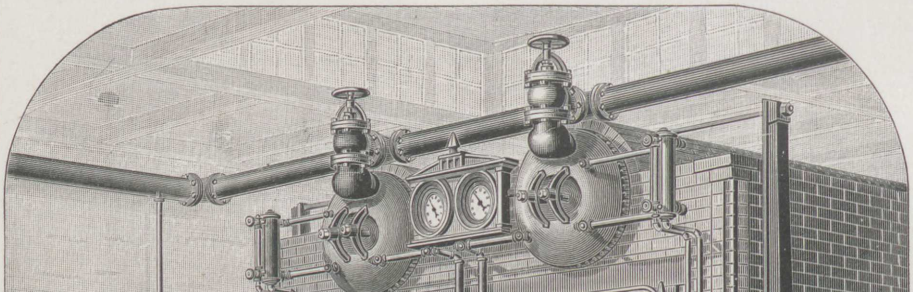
Being made in sections, which are readily put together with a simple expanding tool, these boilers may be easily and cheaply transported where it would be impossible to place a boiler of ordinary construction. They can be made in parts small enough for mule transportation, if required.

##### *17.—Repairs.*

As now constructed these boilers seldom require repairs, but should, from any cause, such be necessary, any good mechanic can make them with the tools usually found in boiler shops. Should a tube require to be renewed it can be removed, and a new one substituted the same as in a tubular boiler.

##### *18.—Practical Experience.*

The above advantages would be worthy of attention if they were only theoretical, but they have been, in fact, demonstrated by the experience of twenty years, under a great variety of circumstances and of treatment. Of the total number sold, less than two-per cent. have, so far as we are aware, been thrown out of use; while a large number of customers have repeated their orders — some a score of times, — as will be seen by the list of references hereto appended.



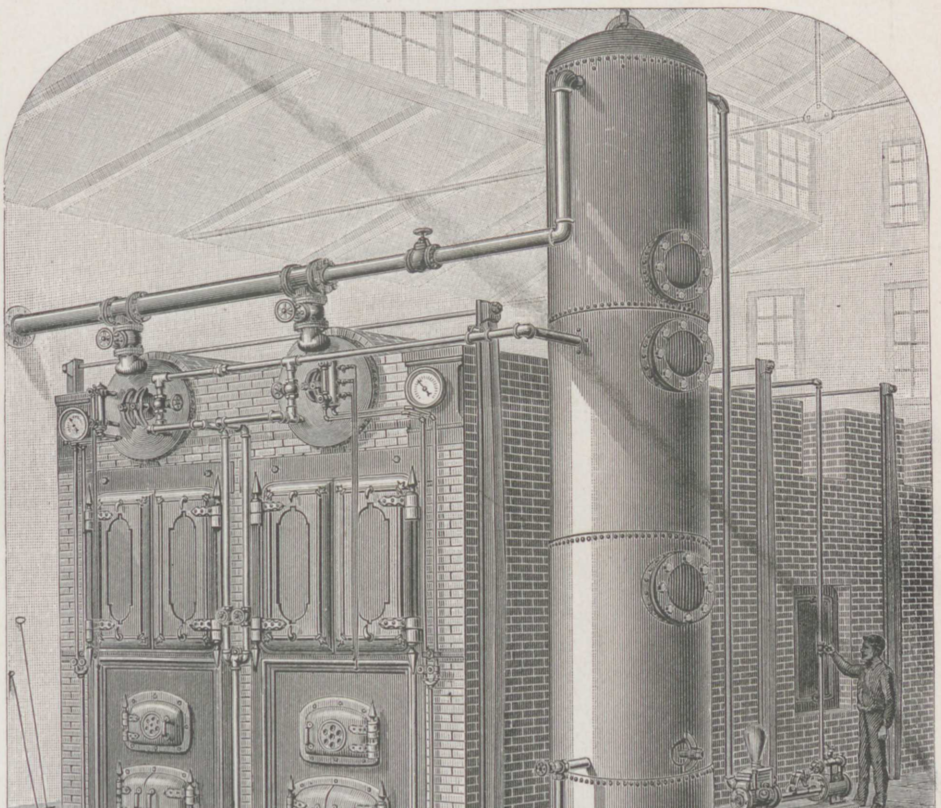

Babcock & Wilcox Boilers, 164 H. P., erected 1884 for Greenfield & Co., Confectioners, Brooklyn, N. Y.

## ECONOMY IN STEAM.

### *Efficiency of the Boiler.*

One pound of pure carbon when burned yields 14,500 heat units, each of which is equal to 772 foot pounds of energy. One pound of carbon, if all its heat was utilized in power, would therefore exert 5.65 horse-power for one hour, instead of from ½ to ¼, as in the best ordinary practice. The 14,500 heat units would, if all utilized in a boiler, evaporate 15 pounds of water from 212° at atmospheric pressure. A boiler which evaporates 7½ pounds of water for each pound of combustible, utilizes but 50 per cent. of the total heat, and this is about the average result of shell boilers now in use.

The Babcock & Wilcox boilers, in *thirty tests* extending over the last twelve years, under a great variety of conditions and circumstances, by no less than twenty different engineers, and, with only two exceptions, on boilers in daily use for manufacturing purposes, in England, Scotland, and from Massachusetts to California in the United States, with various kinds and grades of coals, and at various rates of combustion, covering an aggregate of nearly three months' regular working, and evaporating over three thousand tons of water, gave an average evaporation of 11.4217 pounds water per pound of combustible. This is within *four per cent.* of Rankine's standard, *and within seven and one-half per cent. of the highest theoretical efficiency*, under the conditions in which they were made. It is not probable that any kind of boiler, fairly tested, will ever beat such a record. As about 15 per cent. is lost in the chimney gases, and in radiation, it is evident that all claims to over 12½ pounds evaporation should be looked upon as unreliable.



Babcock & Wilcox Boilers, 272 H.P. at Worombo Mfg. Co., Lisbon Falls, Me.

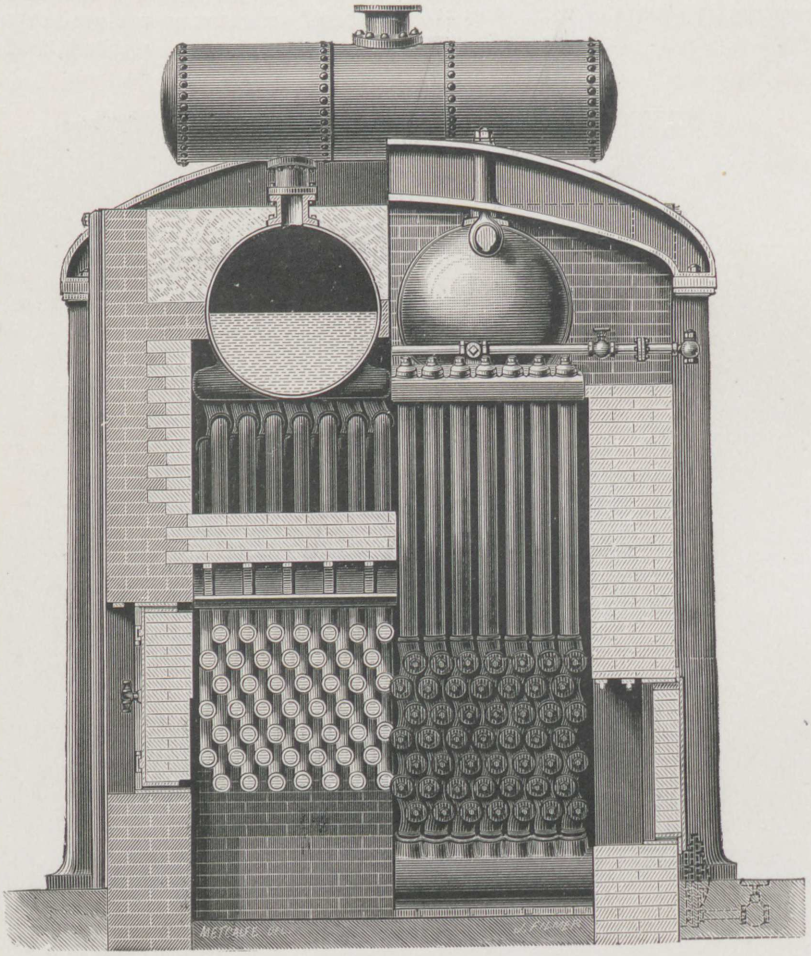
A steam generator is composed of two distinct parts, each with its independent function. The furnace is for the proper combustion of the fuel, and its duty is performed to perfection when the greatest amount, but not necessarily *intensity*, of heat is obtained from the given weight of combustible. The boiler proper is for the transfer of the heat thus generated into useful effect by evaporating water into steam, and its function is fulfilled completely when the greatest possible quantity of heat is thus utilized. To a lack of appreciation of this fact, and of a knowledge of the principles involved, is chargeable much waste of money and disappointment, both to inventors and steam users.

As a boiler is for making steam, it can only utilize for that purpose heat of a greater intensity or higher temperature than the steam itself, therefore the gases of combustion cannot be reduced below that temperature, and the heat thereby represented is lost. The amount of this loss will depend upon the amount of air admitted to the furnace, and the increase of temperature at which it escapes. The more air admitted the greater the loss ; hence the fallacy of all those schemes which admit air above the fire.

The rate of combustion should not exceed 0.3 pound of coal per hour per square foot of heating surface, except where *quantity* of steam is of greater importance than economy of fuel. Where a blast is used the grate surface should be proportionately reduced to secure best economy.

"The maximum conductivity or flow of heat is secured by so designing the boiler as to secure rapid, steady, and complete circulation of the water within it . . . and securing opposite directions of flow for the gases on the one side and the water on the other."—*Prof. R. H. Thurston.*

The accumulation of scale on the interior, and of soot on the exterior, will seriously affect the



VERTICAL SECTION.

Babcock & Wilcox Boiler, at U. S. Centennial Exhibition, 1876. 150 H. P.

efficiency and economy of the boiler. Only one-eighth of an inch deposit of soot renders the heating surface practically useless. Only one-sixteenth of an inch of scale or sediment will cause a loss of 13 per cent. in fuel. A boiler must, therefore, be kept clean, outside and in, to secure a high efficiency.

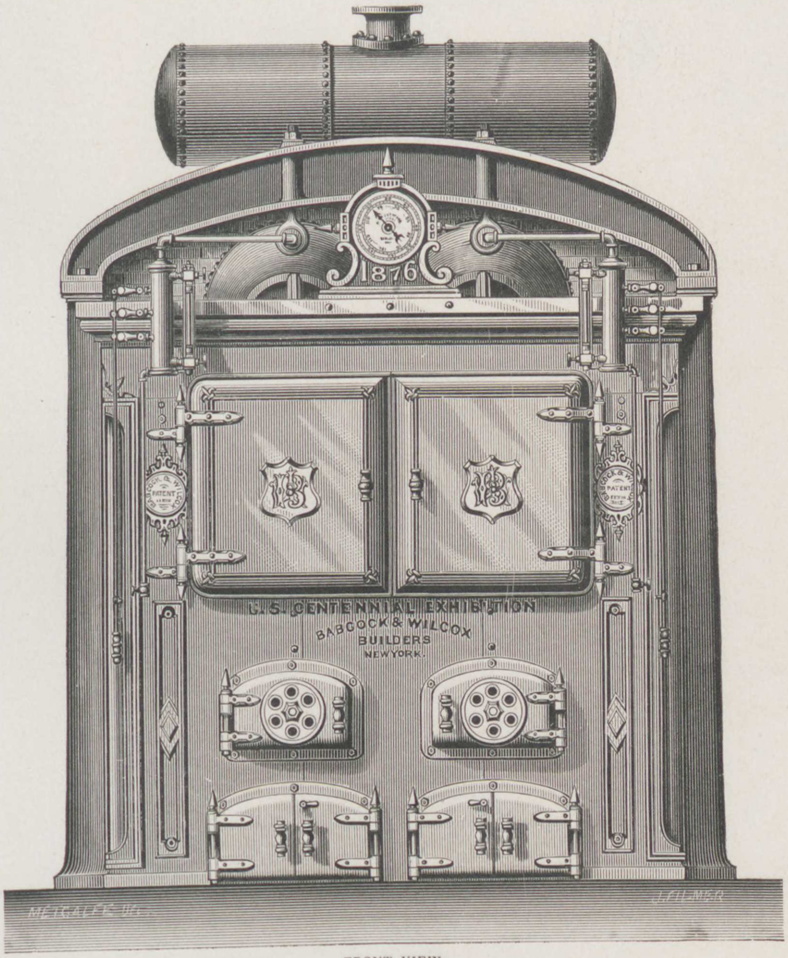
It is never economy to force a boiler, and the best results are always attained with ample boiler power. It is also necessary to keep the boiler, together with its brick work, in good order, and to have careful firing where economy is desired.

The result of a bad setting for a boiler has been known to be a loss of 21 per cent. in economy.

*Efficiency of the Furnace.*

Combustion may be defined as "the union of two dissimilar substances, evolving light and heat." In ordinary practice, one of these is always the oxygen in the atmosphere, and the other is the fuel employed. Every pound of fuel requires a given quantity of oxygen for its complete combustion, and thus a given quantity of air. This varies with different fuels, but in every case less air prevents complete combustion, and an excess of air causes waste of heat to the amount required to heat it to the temperature of the escaping gas.

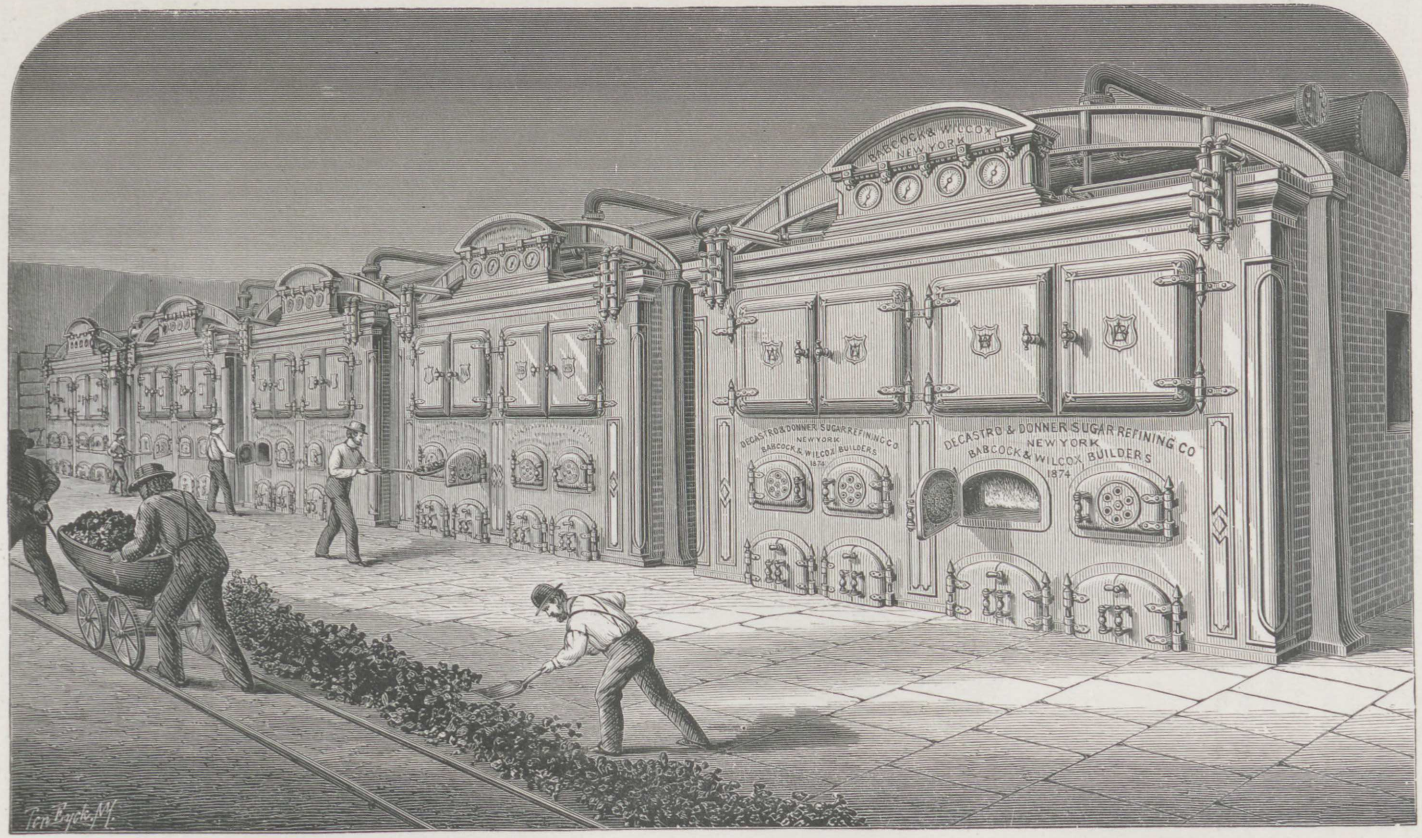
With chimney draft, the experiments of the U. S. Navy show that ordinary furnaces require about twice the theoretical amount of air to secure perfect combustion.




FRONT VIEW.
Babcock & Wilcox Boiler, at U. S. Centennial Exhibition, 1876. 150 H. P.

Prof. Schwackhoffer, of Vienna, found in the boilers used in Europe an average excess of 70 per cent. of the total amount passing through the fire — or that over three times the theoretical amount was used.

A series of analyses by Dr. Behr of the escaping gases from a Babcock & Wilcox boiler, with




1500 H. P. Babcock & Wilcox Boilers, at DeCastro & Donner's Sugar Refining Co.'s Refinery, foot of North 3d St., Brooklyn, E. D. 1200 H. P. erected 1874. 300 H. P. erected 1876.

chimney draft, showed an average excess of air equal to 48 per cent. of the whole quantity.

A series of 12 tests made by same with artificial blast, gave an average excess of only 22 per cent. of the whole quantity, and in a few cases none at all, with only traces of carbonic oxide, showing perfect combustion.

In a summary of experiments made in England, published in Bourne's late large work, "Steam, Air and Gas Engines," it is stated that:

"A moderately thick and hot fire with rapid draft uniformly gave the best results."

"Combustion of black smoke by additional air was a loss."

"In all experiments the highest result was always obtained when all the air was introduced through the fire bars."

"Difference in mode of firing only, may produce a difference of 13 per cent." (in economy).

Different fuels require different furnaces, and no one furnace or grate-bar is equally good for all fuels. The Babcock & Wilcox Co. provide with their boilers, a special furnace, adapted to the particular kind of fuel to be used.

### *Efficiency of the Engine.*

A first-class boiler will deliver to the engine 75 per cent. of all the energy in the combustible, or say 10,875 out of a total of 14,500 heat units, or, allowing about 8 per cent. for ashes, 10,000 heat units for each pound of coal burned. This represents 7,720,000 foot pounds of energy, which, if all utilized by the engine, would give 3.90 horse-power for one hour, or at the rate of 0.26 lbs. coal for each hourly horse-power. But, by the greatest refinement in engines yet accomplished, the cost of a horse-power has not been brought below 1½ lbs. coal per hour, or 17 per cent. of the energy delivered by the boiler, while the average engine uses 3½ lbs. coal per horse-power, and discharges, unutilized, 93 per cent. of the energy delivered to it! The greater part of this loss is in the latent heat of the steam, which is exhausted into the atmosphere, or condenser, and is unavoidable so far as now known. Still, the fact remains that many an ordinary engine uses four times as much steam for the same power as is required by the best engines.

It is economy, therefore, in most cases, to use a high-class engine. There are instances, however, where the engine is used for so short a time in each year, that the saving may not be sufficient to pay the interest on the additional cost, and a cheaper engine, even if comparatively wasteful, may be better economy.

Compound engines, when high pressures can be obtained, have an advantage in economy over single cylinders, and even "triple" and "quadruple" expansion engines under some conditions show a saving over simple "compound." But they require a pressure of from 100 to 200 lbs. and a comparatively steady load to develope their advantages to a great degree. Such pressures can be safely carried on Babcock & Wilcox boilers.

A large boiler is generally an advantage, but it is not economy to use a large engine to develop a small power. Sufficient steam to fill the cylinder at the terminal pressure — each stroke — has to be furnished whether the engine is doing more or less work, and this frequently amounts to far more than the steam used to do the work. Thus, a $24 \times 48$ engine, making 60 revolutions per minute, without "cut-off," uses 30 horse-power of steam in displacing the atmosphere, without exerting any available power. For the same reason back pressure greatly increases the cost of the power.

"Most of the abuses connected with steam engineering have arisen from two causes — avarice and ignorance; avarice on the part of men who are imbued with the idea that cheap boilers and engines are economical, and that these can be operated by a class of men who are willing to work for the lowest wages; ignorance on the part of those who claim to be engineers, but who at the best are mere starters and stoppers." — *J. H. Vail, Gen. Supt. Edison E. L. Co., New York.*

### *Efficiency of Pumping Machines.*

Many engines, from the small "donkey" feed pump to the great water-works engine, are used exclusively for pumping water, and it is usual to reckon their "duty" by the water pumped, expressed in millions of foot pounds for each 100 lbs. coal burned; each million of duty representing about 0.13 of one per cent. of the thermal value of the steam. The following table is based on one given by Chas. E. Emery, Ph. D., in the "Report and Awards, Group XX, U. S. Centennial Exposition:"

TABLE OF EFFICIENCY OF PUMPING MACHINES.

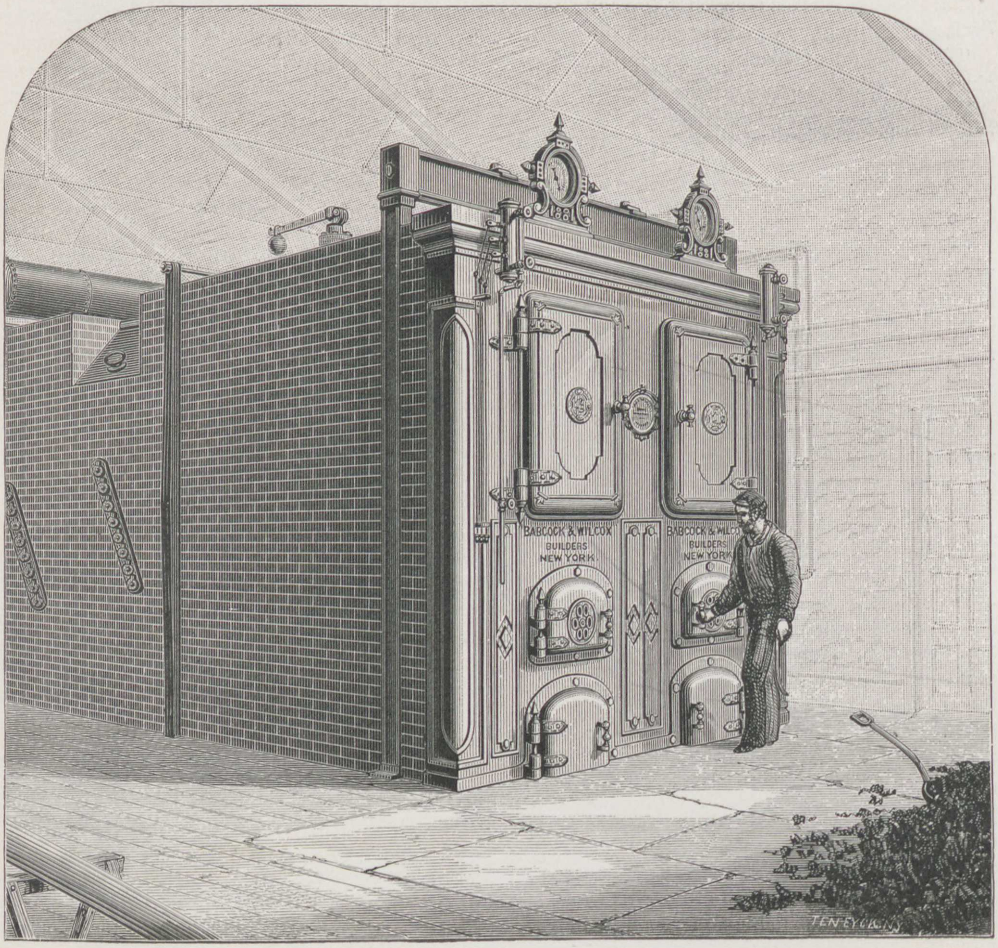
| Description. | Duty in Million Foot Pounds per 110 lbs. Coal. | Per Centage of Thermal Value of Steam Used. | Equivalent in Coal per Hourly Horse-power. |
|---|---|---|---|
| Pumping Engines | 30 to 110 | 3.89 to 13.25 | 6.68 to 1.95 |
| Steam pumps, large size, proportioned for work | 15 to 30 | 1.94 " 3.89 | 13.4 " 6.68 |
| Steam pumps, small size, for ordinary uses | 8 to 15 | 1.04 " 1.94 | 25.00 " 13.40 |
| Vacuum pumps | 3 to 10 | 0.39 " 1.30 | 66.6 " 25.00 |
| Injectors, lifting water only | 2 to 5 | 0.26 " 0.65 | 100 " 66.60 |

### *PROPERTIES OF SATURATED STEAM.*

Ice is liquified and becomes water at 32° F. Above this point water increases in temperature up to the steaming point, nearly at the rate of 1° for each unit of heat added per pound of water. The steaming point (212° at atmospheric pressure), rises as the superimposed pressure increases, but at a decreasing ratio; as, for example, at atmospheric pressure it takes $3\frac{1}{2}$° to add a pound, while at 150 lbs. $\frac{1}{2}$° gives the same increase of pressure.

For each unit of heat added above the steaming point, a portion of the water is converted into steam, having the same temperature and the same pressure as that at which it is evaporated. The heat so absorbed is called "Latent Heat." The amount of heat rendered latent by each pound of water in becoming steam varies at different pressures, decreasing as the pressure increases. This latent heat added to the sensible heat (or the thermometric temperature), constitutes the "Total Heat." The "total heat" being greater as the pressure increases, it will take more heat, and consequently more fuel, to make a pound of steam the higher the pressure.

Saturated steam cannot be cooled except by lowering its pressure, the abstraction of heat being compensated by the latent heat of a portion which is condensed. Neither can steam, in contact with water, be heated above the temperature normal to its pressure.




Babcock & Wilcox Boilers, at The Turner & Seymour Mfg. Co., Torrington, Ct. 100 H. P. Erected 1880-1.

The density of saturated steam varies from $\frac{5}{8}$ that of air of same temperature and pressure, below that of the atmosphere, to $\frac{2}{3}$ at 100 lbs. Its weight per cubic foot varies as the 16 root of the 17th power, and may be found by the formula: $D — .003027 p^{.941}$, which is correct to within $\frac{1}{4}$ per cent. up to 250 lbs. pressure.

The following table gives the properties of steam at different pressures — from 1 lb. to 400.

## SCALE OF PROPERTIES OF SATURATED STEAM.

| Total pressure per square inch. | Temperature in Fahrenheit degrees. | Total Heat in heat units from water at 32° F. | Latent heat, in heat units. | Density or weight of one cubic ft. | Volume of one pound of steam. | Relative volume, or cub. ft. from one of water. | Factor of equivalent evaporation, at 212°. | Total pressure per square inch. |
|---|---|---|---|---|---|---|---|---|
| 1 | 102 | 1113.05 | 1042.964 | .0030 | 330.36 | 20620 | 0.965 | 1 |
| 2 | 126.266 | 1120.45 | 1026.010 | .0058 | 172.08 | 10720 | 0.972 | 2 |
| 3 | 141.622 | 1125.131 | 1015.254 | .0085 | 117.52 | 7326 | 0.977 | 3 |
| 4 | 153.070 | 1128.625 | 1007.229 | .0112 | 89.62 | 5600 | 0.981 | 4 |
| 5 | 162.330 | 1131.449 | 1000.727 | .0137 | 72.66 | 4535 | 0.984 | 5 |
| 6 | 170.123 | 1133.826 | 995.219 | .0163 | 61.21 | 3814 | 0.986 | 6 |
| 7 | 176.910 | 1135.896 | 990.471 | .0189 | 52.94 | 3300 | 0.988 | 7 |
| 8 | 182.910 | 1137.726 | 986.245 | .0214 | 46.69 | 2910 | 0.990 | 8 |
| 9 | 188.316 | 1139.375 | 982.434 | .0239 | 41.79 | 2607 | 0.992 | 9 |
| 10 | 193.240 | 1140.877 | 978.958 | .0264 | 31.84 | 2360 | 0.994 | 10 |
| 15 | 213.025 | 1146.912 | 964.973 | .0387 | 25.85 | 1612 | 1.000 | 15 |
| 20 | 227.917 | 1151.454 | 954.415 | .0511 | 19.72 | 1220.3 | 1.005 | 20 |
| 25 | 240.000 | 1155.139 | 945.825 | .0634 | 15.99 | 984.8 | 1.008 | 25 |
| 30 | 250.245 | 1158.263 | 938.925 | .0755 | 13.46 | 826.8 | 1.012 | 30 |
| 35 | 259.176 | 1160.987 | 932.152 | .0875 | 11.65 | 713.4 | 1.015 | 35 |
| 40 | 267.120 | 1163.410 | 926.472 | .0994 | 10.27 | 628.2 | 1.017 | 40 |
| 45 | 274.296 | 1165.600 | 921.334 | .1111 | 9.18 | 561.8 | 1.019 | 45 |
| 50 | 280.854 | 1167.600 | 916.631 | .1227 | 8.31 | 508.5 | 1.021 | 50 |
| 55 | 286.897 | 1169.442 | 912.290 | .1343 | 7.61 | 464.7 | 1.023 | 55 |
| 60 | 292.520 | 1171.158 | 908.247 | .1457 | 7.01 | 428.5 | 1.025 | 60 |
| 65 | 297.777 | 1172.762 | 904.462 | .1569 | 6.49 | 397.7 | 1.027 | 65 |
| 70 | 302.718 | 1174.269 | 900.899 | .1681 | 6.07 | 371.2 | 1.028 | 70 |
| 75 | 307.388 | 1175.692 | 897.526 | .1792 | 5.68 | 348.3 | 1.030 | 75 |
| 80 | 311.812 | 1177.042 | 894.330 | .1901 | 5.35 | 328.3 | 1.031 | 80 |
| 85 | 316.021 | 1178.326 | 891.286 | .2010 | 5.05 | 310.5 | 1.033 | 85 |
| 90 | 320.039 | 1179.551 | 888.375 | .2118 | 4.79 | 294.7 | 1.034 | 90 |
| 95 | 323.884 | 1180.724 | 885.588 | .2224 | 4.55 | 280.6 | 1.035 | 95 |
| 100 | 327.571 | 1181.849 | 883.914 | .2330 | 4.33 | 267.9 | 1.036 | 100 |
| 105 | 331.113 | 1182.929 | 880.342 | .2434 | 4.14 | 265.5 | 1.037 | 105 |
| 110 | 334.523 | 1183.970 | 877.865 | .2537 | 3.97 | 246.0 | 1.038 | 110 |
| 115 | 337.814 | 1184.974 | 875.472 | .2640 | 3.80 | 236.3 | 1.039 | 115 |
| 120 | 340.995 | 1185.944 | 873.155 | .2742 | 3.65 | 227.6 | 1.040 | 120 |
| 125 | 344.074 | 1186.883 | 870.911 | .2842 | 3.51 | 219.7 | 1.041 | 125 |
| 130 | 347.059 | 1187.794 | 868.735 | .2942 | 3.38 | 212.3 | 1.042 | 130 |
| 140 | 352.757 | 1189.535 | 864.566 | .3138 | 3.16 | 199.0 | 1.044 | 140 |
| 150 | 358.161 | 1191.180 | 860.621 | .3340 | 2.96 | 187.5 | 1.046 | 150 |
| 160 | 363.277 | 1192.741 | 856.874 | .3520 | 2.79 | 177.3 | 1.047 | 160 |
| 170 | 368.158 | 1194.228 | 853.294 | .3709 | 2.63 | 168.4 | 1.049 | 170 |
| 180 | 372.822 | 1195.650 | 849.869 | .3889 | 2.49 | 160.4 | 1.051 | 180 |
| 190 | 377.291 | 1197.013 | 846.584 | .4072 | 2.37 | 153.4 | 1.052 | 190 |
| 200 | 381.573 | 1198.319 | 843.432 | .4249 | 2.26 | 147.1 | 1.053 | 200 |
| 250 | 401.072 | 1203.735 | 831.222 | .5464 | 1.83 | 114 | 1.059 | 250 |
| 300 | 418.225 | 1208.737 | 819.610 | .6486 | 1.54 | 96 | 1.064 | 300 |
| 350 | 431.956 | 1212.580 | 810.690 | .7498 | 1.33 | 83 | 1.068 | 350 |
| 400 | 444.919 | 1217.094 | 800.193 | .8502 | 1.18 | 73 | 1.073 | 400 |

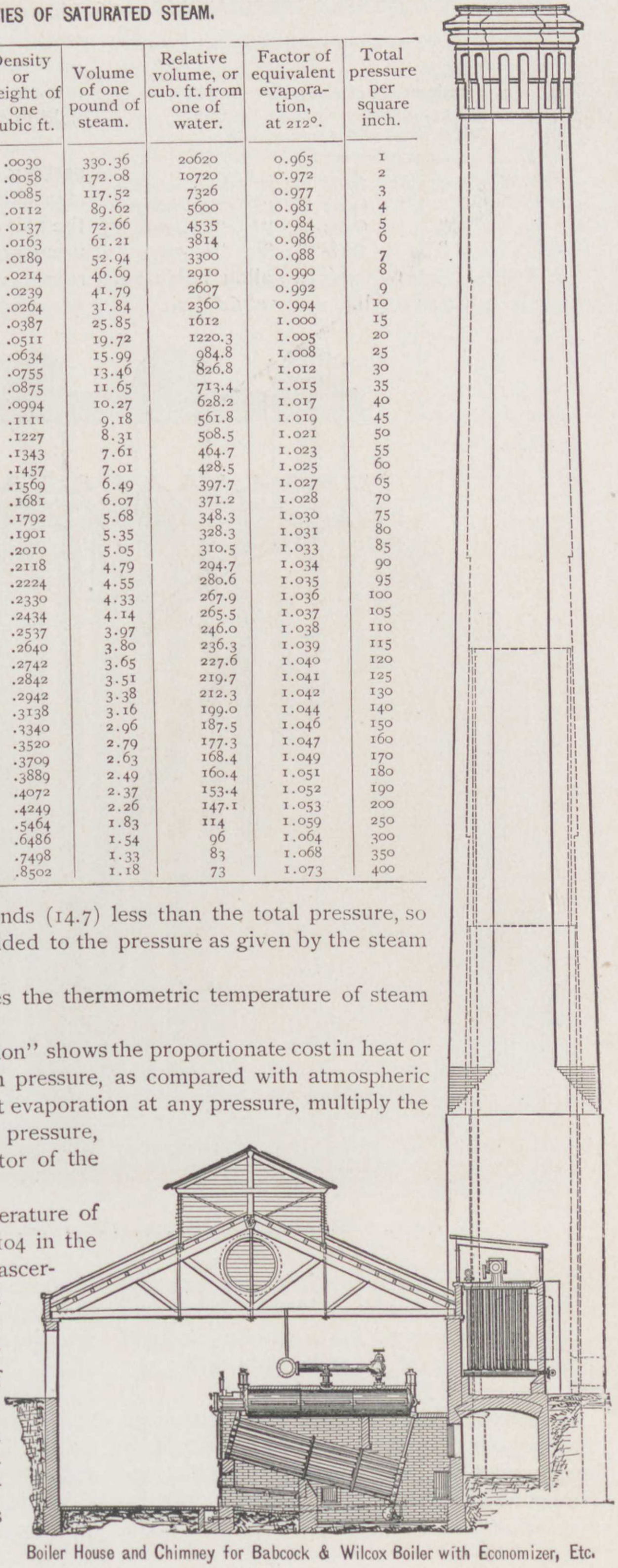
The gauge pressure is about 15 pounds (14.7) less than the total pressure, so that in using this table, 15 must be added to the pressure as given by the steam gauge.

The column of Temperatures gives the thermometric temperature of steam and boiling point at each pressure.

The "factor of equivalent evaporation" shows the proportionate cost in heat or fuel, of producing steam at the given pressure, as compared with atmospheric pressure. To ascertain the equivalent evaporation at any pressure, multiply the given evaporation by the factor of its pressure, and divide the quotient by the factor of the desired pressure.

Each degree of difference in temperature of feed-water, makes a difference of .00104 in the amount of evaporation. Hence, to ascertain the equivalent evaporation from any other temperature of feed than 212°, add to the factor given as many times .00104 as the temperature of feed-water is degrees below 212°.

For other pressures than those given in the table, it will be practically correct to take the proportion of the difference between the nearest pressures given in the table.



Boiler House and Chimney for Babcock & Wilcox Boiler with Economizer, Etc.

### *WATER AT DIFFERENT TEMPERATURES.*

There are four notable temperatures for pure water, viz :—

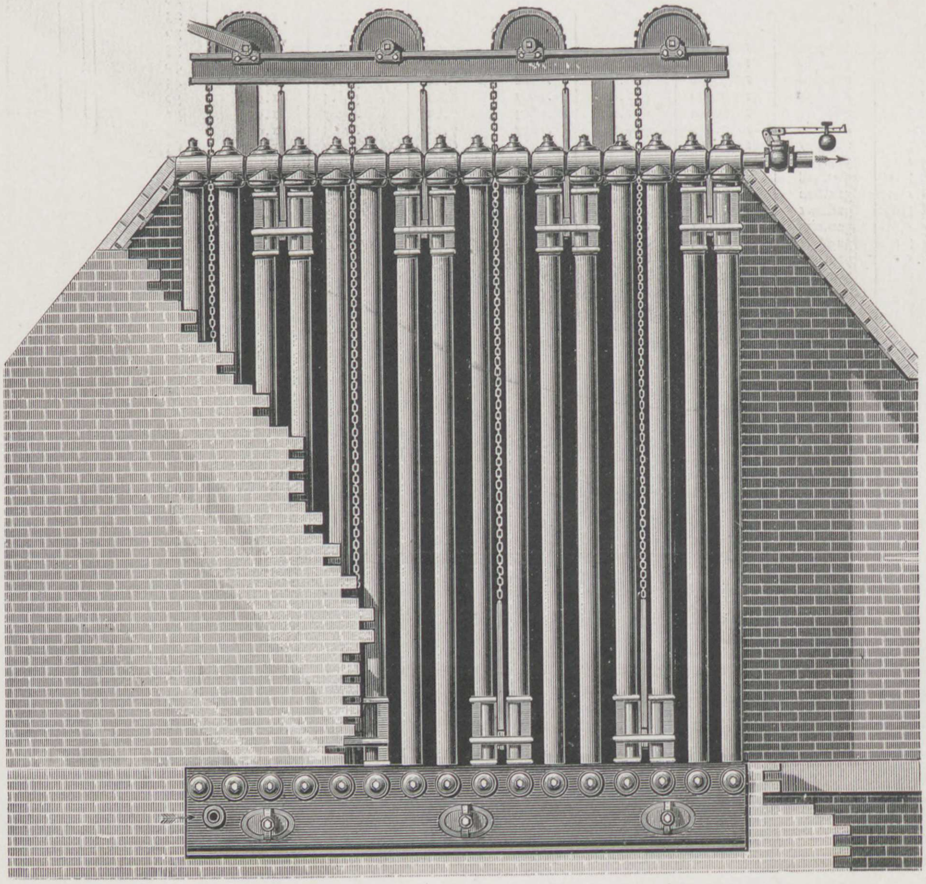
1. Freezing point at sea level, 32° F.
2. Point of maximum density, 39.1° F.
3. British standard for spec. gr. 62° F.
4. Boiling point at sea level, 212° F.

| | | | |
|---|---|---|---|
| 32° F. | Weight per cub.ft. | 62,418 lbs.; | per cub.in. .03612 lbs. |
| 39.1° F. | " " " | 62,425 " | " " .036125 " |
| 62° F. | " " " | 62,355 " | " " .03608 " |
| 212° F. | " " " | 59,760 " | " " .03458 " |

A United States Standard gallon holds 231 cubic inches, and 8⅓ lbs. water at 62° Fah.

Lime salts are more soluble in cold than in hot water, and most of them are deposited at 320°, or less. When frozen into ice, or evaporated into steam, water parts with nearly all substances held in solution.

Water has a greater specific heat, or heat-absorbing capacity, than any other known substance (bromine and hydrogen excepted), and is the unit of comparison employed for all measurements of the capacities for heat of all substances whatever. The specific heat of water is not constant, but rises in an increasing ratio with



Babcock & Wilcox Patent Fuel Economizer, at Bound Brook Woolen Mills, Bound Brook, N. J.

A British Imperial gallon holds 277,274 cubic inches and 10 lbs. water at 62° Fah.

*Sea water* (average) has a specific gravity of 1.028, boils at 213.2° F., and weighs 64 lbs. per cubic foot at 62° F.

In solvent power water has a greater range than any other liquid. For common salt this is nearly constant at all temperatures, while it increases with increase of temperature for others, magnesium and sodium sulphates, for instance.

the temperature, so that it requires more heat, the higher the temperature, to raise a given quantity of water from one temperature to another. Thus, the specific heat at 32° being 1, at 212° it is 1.013, and at 320° (the temperature of 75 lbs. steam pressure) it is 1.0294. The specific heat of ice and steam are respectively .504 and .475, or practically about half that of water.

A British Thermal Unit (or heat unit) is that quantity of heat which will raise one pound of water at or about the freezing point, 1° Fahrenheit. A French "Caloric" is the heat required to raise one kilogramme of water 1° centigrade, and is equal to 3.96832 British thermal units.

A pressure of 1 lb. per sq. in. is exerted by a column of water 2.3093 ft., or 27.71 in. high, at 62° F.

The following table gives the number of British thermal units in a pound of water at different temperatures. They are reckoned above 32° Fah., for, strictly speaking, *water* does not exist below 32°, and ice follows another law.

WATER BETWEEN 32° AND 212° F.

| Temperature Fah. | Heat Units per lb. | Weight, lbs. per cub. ft. | Temperature Fah. | Heat Units per lb. | Weight, lbs. per cub. ft. |
|---|---|---|---|---|---|
| 32° | 0. | 62.42 | 145 | 113.28 | 61.28 |
| 35 | 3. | 62.42 | 146 | 114.28 | 61.26 |
| 40 | 8. | 62.42 | 147 | 115.29 | 61.24 |
| 45 | 13. | 62.42 | 148 | 116.29 | 61.22 |
| 50 | 18. | 62.41 | 149 | 117.30 | 61.20 |
| 52 | 20. | 62.40 | 150 | 118.31 | 61.18 |
| 54 | 22.01 | 62.40 | 151 | 119.31 | 61.16 |
| 56 | 24.01 | 62.39 | 152 | 120.32 | 61.14 |
| 58 | 26.01 | 62.38 | 153 | 121.33 | 61.12 |
| 60 | 28.01 | 62.37 | 154 | 122.33 | 61.10 |
| 62 | 30.01 | 62.36 | 155 | 123.34 | 61.08 |
| 64 | 32.01 | 62.35 | 156 | 124.35 | 61.06 |
| 66 | 34.02 | 62.34 | 157 | 125.35 | 61.04 |
| 68 | 36.02 | 62.33 | 158 | 126.36 | 61.02 |
| 70 | 38.02 | 62.31 | 159 | 127.37 | 61.00 |
| 72 | 40.02 | 62.30 | 160 | 128.37 | 60.98 |
| 74 | 42.03 | 62.28 | 161 | 129.38 | 60.96 |
| 76 | 44.03 | 62.27 | 162 | 130.39 | 60.94 |
| 78 | 46.03 | 62.25 | 163 | 131.40 | 60.92 |
| 80 | 48.04 | 62.23 | 164 | 132.41 | 60.90 |
| 82 | 50.04 | 62.21 | 165 | 133.41 | 60.87 |
| 84 | 52.04 | 62.19 | 166 | 134.42 | 60.85 |
| 86 | 54.05 | 62.17 | 167 | 135.43 | 60.83 |
| 88 | 56.05 | 62.15 | 168 | 136.44 | 60.81 |
| 90 | 58.06 | 62.13 | 169 | 137.45 | 60.79 |
| 92 | 60.06 | 62.11 | 170 | 138.45 | 60.77 |
| 94 | 62.06 | 62.09 | 171 | 139.46 | 60.75 |
| 96 | 64.07 | 62.07 | 172 | 140.47 | 60.73 |
| 98 | 66.07 | 62.05 | 173 | 141.48 | 60.70 |
| 100 | 68.08 | 62.02 | 174 | 142.49 | 60.68 |
| 102 | 70.09 | 62.00 | 175 | 143.50 | 60.66 |
| 104 | 72.09 | 61.97 | 176 | 144.51 | 60.64 |
| 106 | 74.10 | 61.95 | 177 | 145.52 | 60.62 |
| 108 | 76.10 | 61.92 | 178 | 146.52 | 60.59 |
| 110 | 78.11 | 61.89 | 179 | 147.53 | 60.57 |
| 112 | 80.12 | 61.86 | 180 | 148.54 | 60.55 |
| 113 | 81.12 | 61.84 | 181 | 149.55 | 60.53 |
| 114 | 82.13 | 61.83 | 182 | 150.56 | 60.50 |
| 115 | 83.13 | 61.82 | 183 | 151.57 | 60.48 |
| 116 | 84.13 | 61.80 | 184 | 152.58 | 60.46 |
| 117 | 85.14 | 61.78 | 185 | 153.59 | 60.44 |
| 118 | 86.14 | 61.77 | 186 | 154.60 | 60.41 |
| 119 | 87.15 | 61.75 | 187 | 155.61 | 60.39 |
| 120 | 88.15 | 61.74 | 188 | 156.62 | 60.37 |
| 121 | 89.15 | 61.72 | 180 | 157.63 | 60.34 |
| 122 | 90.16 | 61.70 | 190 | 158.64 | 60.32 |
| 123 | 91.16 | 61.68 | 191 | 159.65 | 60.29 |
| 124 | 92.17 | 61.67 | 192 | 160.67 | 60.27 |
| 125 | 93.17 | 61.65 | 193 | 161.68 | 60.25 |
| 126 | 94.17 | 61 63 | 194 | 162.69 | 60.22 |
| 127 | 95.18 | 61.61 | 195 | 163.70 | 60.20 |
| 128 | 96.18 | 61.60 | 196 | 164.71 | 60.17 |
| 129 | 97.19 | 61.58 | 197 | 165.72 | 60.15 |
| 130 | 98.19 | 61.56 | 198 | 166.73 | 60.12 |
| 131 | 99.20 | 61.54 | 199 | 167.74 | 60.10 |
| 132 | 100.20 | 61.52 | 200 | 168.75 | 60.07 |
| 133 | 101.21 | 61.51 | 201 | 169.77 | 60.05 |
| 134 | 102.21 | 61.49 | 202 | 170.78 | 60.02 |
| 135 | 103.22 | 61.47 | 203 | 171.79 | 60.00 |
| 136 | 104.22 | 61.45 | 204 | 172.80 | 59.97 |
| 137 | 105.23 | 61.43 | 205 | 173.81 | 59.95 |
| 138 | 106.23 | 61.41 | 206 | 174.83 | 59.92 |
| 139 | 107.24 | 61.39 | 207 | 175.84 | 56.89 |
| 140 | 108.25 | 61.37 | 208 | 176.85 | 59.87 |
| 141 | 109.25 | 61.36 | 209 | 177.86 | 59.84 |
| 142 | 110.26 | 61.34 | 210 | 178.87 | 59.82 |
| 143 | 111.26 | 61.32 | 211 | 179.89 | 59.79 |
| 144 | 112.27 | 61.30 | 212 | 180.90 | 59.76 |

## *HEATING FEED-WATER.*

The feed-water furnished to steam boilers has to be heated from the normal temperature to that of the steam before evaporation can commence, and this generally at the expense of the fuel which should be utilized in making steam. This temperature at 75 lbs. pressure is 320°, and if we take 60° as the average temperature of feed, we have 260 units of heat per pound, which, as it takes 1151 units to evaporate a pound from 60°, represents a loss of 22.5 per cent. of fuel. All of this heat, therefore, which can be imparted to the feed-water is just so much saved, not only in cost of fuel, but in capacity of boiler. But it is essential that it be done by heat which would otherwise be wasted. All heat imparted to feed-water by injectors and "live-steam heaters," comes from the fuel and represents no saving.

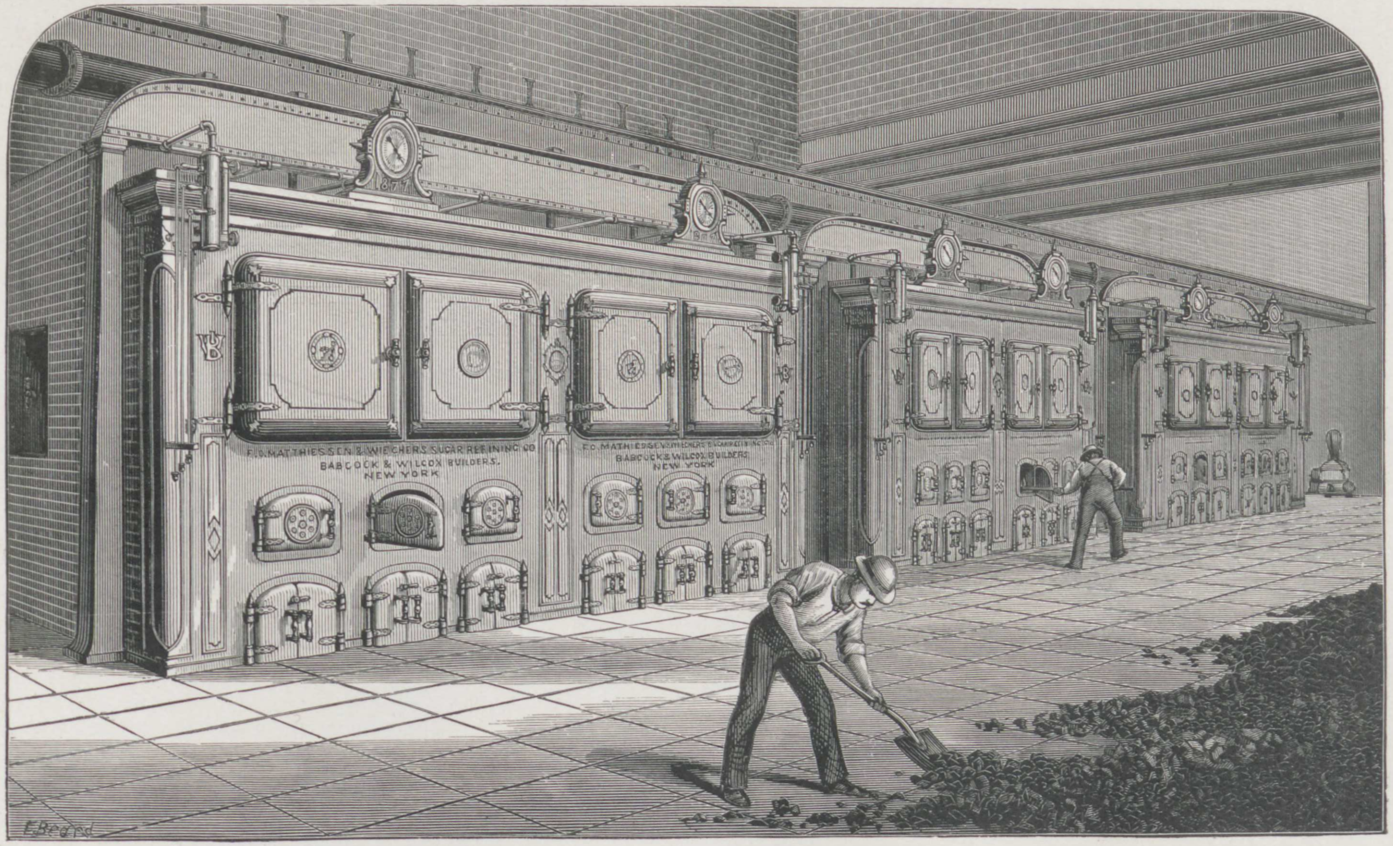
There are two sources of waste heat available for this purpose — exhaust steam and chimney gases. By the former, water may be heated to 200°, or possibly to 210°, in a well proportioned heater.

The gases going to the chimney carry off on an average, according to good authority, 51 per cent. of the fuel, and in the most economical boiler this cannot be reduced below 12 per cent. Some proportion of this is always available for heating the feed-water, by what are known as "economizers," and frequently it may be carried nearly to the temperature of high pressure steam, making a saving in some instances of 20 per cent. The more wasteful the boiler, the greater the benefit of the economizer; but for large plants it is always a valuable adjunct. In many cases water heated by exhaust steam may be still further heated in an economizer, to advantage.

SAVING OF FUEL BY HEATING FEED-WATER. (IN PER CENT.)

(STEAM AT SIXTY POUNDS.)

| Initial Tem. of Water. | FINAL TEMPERATURE OF FEED-WATER. | | | | | | |
|---|---|---|---|---|---|---|---|
| | 120 | 140 | 160 | 180 | 200 | 250 | 300 |
| 32° | 7.50 | 9.20 | 10.90 | 12.36 | 14.30 | 19.03 | 22.90 |
| 35 | 7.25 | 8.96 | 10.66 | 12.09 | 14.09 | 18.34 | 22.60 |
| 40 | 6.85 | 8.57 | 10.28 | 12.00 | 13.71 | 17.99 | 22.27 |
| 45 | 6.45 | 8.17 | 9.90 | 11.61 | 13.34 | 17.64 | 21.94 |
| 50 | 6.05 | 7.71 | 9.50 | 11.23 | 13.00 | 17.28 | 21.61 |
| 55 | 5.64 | 7.37 | 9.06 | 10.85 | 13.60 | 16.93 | 21.27 |
| 60 | 5.23 | 6.97 | 8.72 | 10.46 | 12.20 | 16.58 | 20.92 |
| 65 | 4.82 | 6.56 | 8.32 | 10.07 | 11.82 | 16.20 | 20.58 |
| 70 | 4.40 | 6.15 | 7.91 | 9.68 | 11.43 | 15.83 | 20.23 |
| 75 | 3.98 | 5.74 | 7.50 | 9.28 | 11.04 | 15.46 | 19.88 |
| 80 | 3.55 | 5.32 | 7.09 | 8.87 | 10.65 | 15.08 | 19.52 |
| 85 | 3.12 | 4.90 | 6.63 | 8.46 | 10.25 | 14.70 | 19.17 |
| 90 | 2.68 | 4.47 | 6.26 | 8.06 | 9.85 | 14.32 | 18.81 |
| 95 | 2.24 | 4.04 | 5.84 | 7.65 | 9.44 | 13.94 | 18.44 |
| 100 | 1.80 | 3.61 | 5.42 | 7.23 | 9.03 | 13.55 | 18.07 |
| 110 | .90 | 2.73 | 4.55 | 3.38 | 8.20 | 12.76 | 17.28 |
| 120 | 0 | 1.84 | 3.67 | 5.52 | 7.36 | 11.95 | 16.49 |
| 130 | | .92 | 2.77 | 4.64 | 6.99 | 11.14 | 15.24 |
| 140 | | 0 | 1.87 | 3.75 | 5.62 | 10.31 | 14.99 |
| 150 | | | .94 | 2.83 | 4.72 | 9.46 | 14.18 |
| 160 | | | 0 | 1.91 | 3.82 | 8.59 | 13.37 |
| 170 | | | | .96 | 2.89 | 7.71 | 12.54 |
| 180 | | | | 0 | 1.96 | 6.81 | 11.70 |
| 190 | | | | | .90 | 5.90 | 10.82 |
| 200 | | | | | 0 | 4.85 | 9.93 |




Babcock & Wilcox Boilers, at F. O. Matthiessen & Wiecher's Sugar Refining Co., Jersey City, N. J. 2d Order. 1500 H. P. Erected 1877.

### *FUEL.*

The value of any fuel is measured by the number of heat units which its combustion will generate, a unit of heat being the amount required to heat one pound of water one degree Fahrenheit. The fuel used in generating steam is composed of carbon and hydrogen, and ash, with sometimes small quantities of other substances not materially affecting its value.

"Combustible" is that portion which will burn; the ash or residue varying from 2 to 36 per cent. in different fuels.

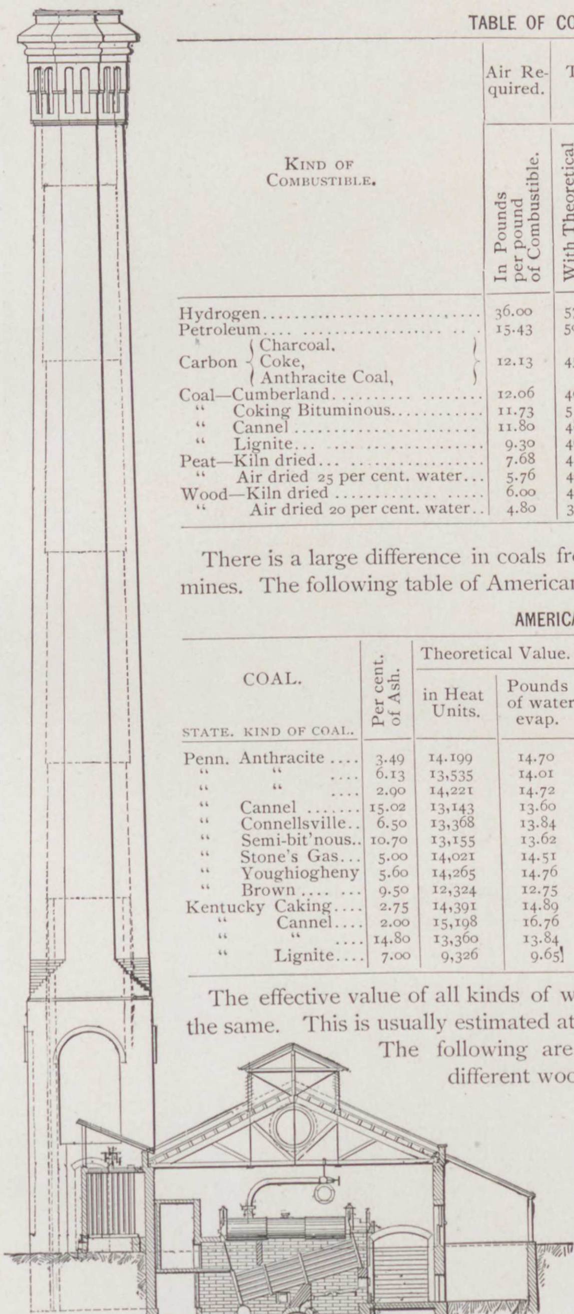


**TABLE OF COMBUSTIBLES.**

| Kind of Combustible. | Air Required. | Temperature of Combustion. | | | | Theoretical Value. | | Highest Attainable Value under Boiler. | |
|---|---|---|---|---|---|---|---|---|---|
| | In Pounds per pound of Combustible. | With Theoretical Supply of Air. | With 1½ Times the Theoretical Supply of Air. | With Twice the Theoretical Supply of Air. | With Three Times the Theoretical Supply of Air. | In Pounds of Water raised 1° per pound of Combustible. | In Pounds of Water evaporated from & at 212°, with 1 lb. Combustible. | With Chimney Draft. | With Blast, Theoretical Supply of Air at 60°, Gas 320° |
| Hydrogen | 36.00 | 5750 | 3860 | 2860 | 1940 | 62032 | 64.20 | | |
| Petroleum | 15.43 | 5050 | 3515 | 2710 | 1850 | 21000 | 21.74 | 18.55 | 19.90 |
| Carbon { Charcoal, Coke, Anthracite Coal, } | 12.13 | 4580 | 3215 | 2440 | 1650 | 14500 | 15.00 | 13.30 | 14.14 |
| Coal—Cumberland | 12.06 | 4900 | 3360 | 2550 | 1730 | 15370 | 15.90 | 14.28 | 15.06 |
| " Coking Bituminous | 11.73 | 5140 | 3520 | 2680 | 1810 | 15837 | 16.00 | 14.45 | 15.19 |
| " Cannel | 11.80 | 4850 | 3330 | 2540 | 1720 | 15080 | 15.60 | 14.01 | 14.76 |
| " Lignite | 9.30 | 4600 | 3210 | 2490 | 1670 | 11745 | 12.15 | 10.78 | 11.46 |
| Peat—Kiln dried | 7.68 | 4470 | 3140 | 2420 | 1660 | 9660 | 10.00 | 8.92 | 9.42 |
| " Air dried 25 per cent. water | 5.76 | 4000 | 2820 | 2240 | 1550 | 7000 | 7.25 | 6.41 | 6.78 |
| Wood—Kiln dried | 6.00 | 4080 | 2910 | 2260 | 1530 | 7245 | 7.50 | 6.64 | 7.02 |
| " Air dried 20 per cent. water | 4.80 | 3700 | 2607 | 2100 | 1490 | 5600 | 5.80 | 4.08 | 4.39 |

There is a large difference in coals from different localities, and even adjacent mines. The following table of American coals, is compiled from various sources:

**AMERICAN COALS.**

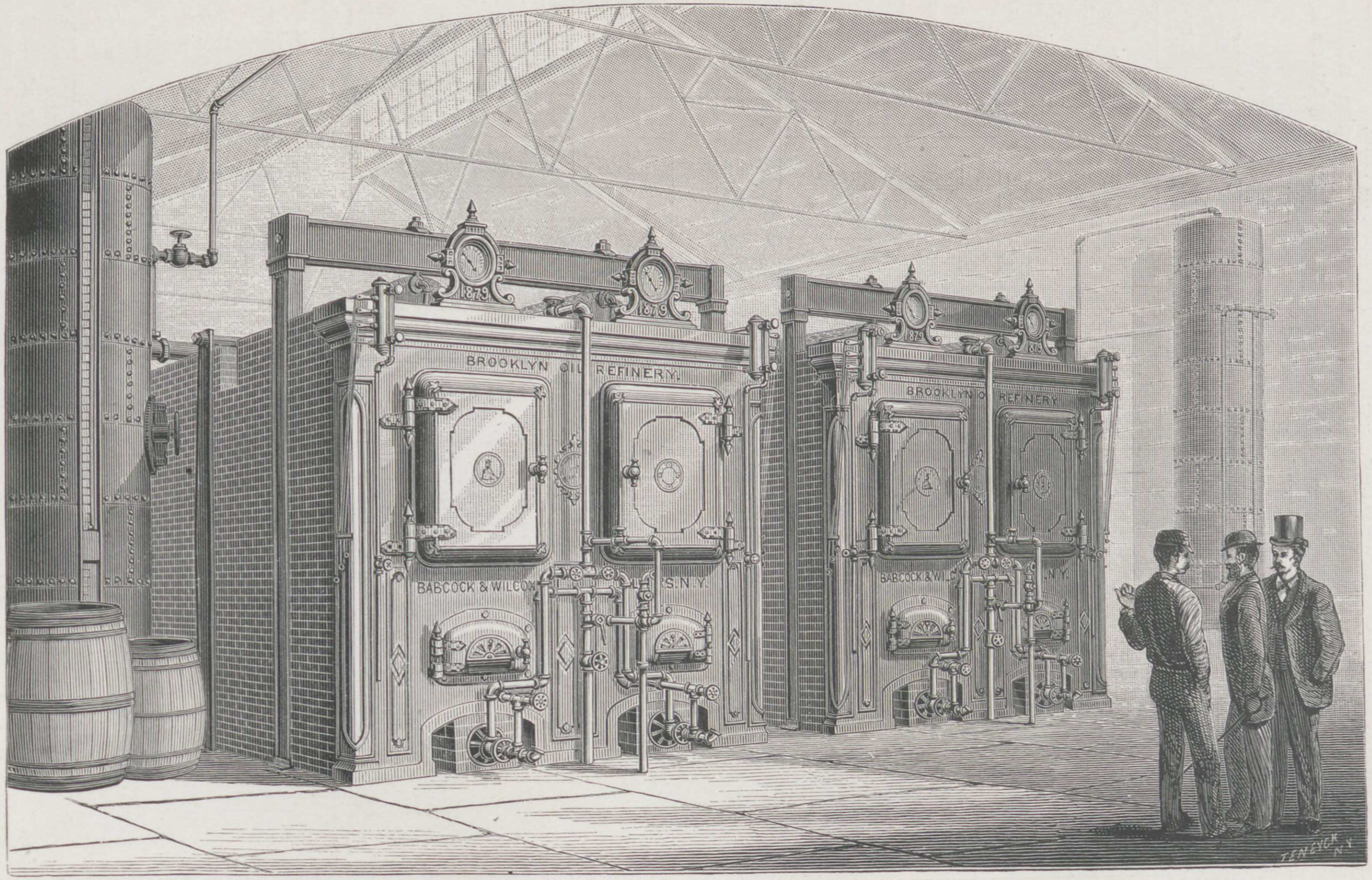
| COAL. State. Kind of Coal. | Per cent. of Ash. | Theoretical Value. in Heat Units. | Theoretical Value. Pounds of water evap. | COAL. State. Kind of Coal. | Per cent of Ash. | Theoretical Value in Heat Units. | Theoretical Value Pounds of water evap. |
|---|---|---|---|---|---|---|---|
| Penn. Anthracite | 3.49 | 14.199 | 14.70 | Ill. Bureau Co. | 5.20 | 13,025 | 13.48 |
| " " | 6.13 | 13,535 | 14.01 | " Mercer Co. | 5.60 | 13,123 | 13.58 |
| " " | 2.90 | 14,221 | 14.72 | " Montauk | 5.50 | 12,659 | 13.10 |
| " Cannel | 15.02 | 13,143 | 13.60 | Ind. Block | 2.50 | 13,588 | 14.38 |
| " Connellsville | 6.50 | 13,368 | 13.84 | " Caking | 5.66 | 14.146 | 14.64 |
| " Semi-bit'nous | 10.70 | 13,155 | 13.62 | " Cannel | 6.00 | 13,097 | 13.56 |
| " Stone's Gas | 5.00 | 14,021 | 14.51 | Md. Cumberland | 13.88 | 12,226 | 12.65 |
| " Youghiogheny | 5.60 | 14,265 | 14.76 | Ark. Lignite | 5.00 | 9,215 | 9.54 |
| " Brown | 9.50 | 12,324 | 12.75 | Col. " | 9.25 | 13,562 | 14.04 |
| Kentucky Caking | 2.75 | 14,391 | 14.89 | " " | 4.50 | 13,866 | 14.35 |
| " Cannel | 2.00 | 15,198 | 16.76 | Texas " | 4.50 | 12,962 | 13.41 |
| " " | 14.80 | 13,360 | 13.84 | Wash. Ter. Lignite | 3.40 | 11,551 | 11.96 |
| " Lignite | 7.00 | 9,326 | 9.65 | Penn. Petroleum | | 20,746 | 21.47 |

The effective value of all kinds of wood *per pound*, when dry, is substantially the same. This is usually estimated at 0.4 the value of the same weight of coal. The following are the weights and comparative value of different woods by the cord:

| Kind of Wood. | Wght. | Kind of Wood. | Wght. |
|---|---|---|---|
| Hickory, Shell bark. | 4469 | Beech | 3126 |
| " Red heart. | 3705 | Hard Maple | 2878 |
| White Oak | 3821 | Southern Pine | 3375 |
| Red Oak | 3254 | Virginia " | 2680 |
| Spruce | 2325 | Yellow " | 1904 |
| New Jersey Pine | 2137 | White " | 1868 |

Boiler House and Chimney for Babcock & Wilcox Boilers, 2000 H. P., with Artificial Blast, Economizer, etc.

The first table gives, for the more common combustibles, the air required for complete combustion, the temperature with different proportions of air, the theoretical value, and the highest attainable




400 H. P. Babcock & Wilcox Boilers, at Standard Oil Co.'s Brooklyn Oil Refinery. Erected in 1878. With Apparatus for burning Tar or Petroleum.

value under a steam boiler, assuming that the gases pass off at 320°, the temperature of steam at 75 lbs. pressure, and the incoming draft to be at 60°; also that with chimney draft twice and with blast only the theoretical amount of air is required for combustion.

The relative value of different fuels is largely a question of locality and transportation. For instance, in some parts of Central America they burn rosewood under their boilers, because it is cheaper than coal; while a few years ago in the West it was found, during a coal famine, that Indian corn was the cheapest fuel they could burn. In some places they burn manure only. The Babcock & Wilcox boilers of Chicago cable railways are run regularly on the offal from the stables of the horse roads, a very small proportion of coal being used to keep it alight.

"Slack" or the screenings from coal, when properly mixed—anthracite and bituminous,—and burned by means of a blower on a grate adapted to it, is nearly equal in value of combustible to coal, but its percentage of refuse is greater.

A number of firms are using slack with decided economy, under Babcock & Wilcox boilers, in which there is ample space below the tubes for the dust to accumulate without covering heating surface or impairing the draft.

Much is said nowadays about the wonderful saving which is to be expected from the use of *petroleum for fuel.* This is all a myth, and a moment's attention to facts is sufficient to convince any one that no such possibility exists. Petroleum has a heating capacity, when fully burned, equal to from 21,000 to 22,000 B. T. U. per pound, or say 50 per cent. more than coal. But owing to the ability to burn it with less losses, it has been found through extended experiments by the pipe lines that under the same boilers, and doing the same work, a pound of petroleum is equal to 1·8 pounds of coal. The experiments on locomotives in Russia have shown practically the same value, or 1·77. Now, a gallon of petroleum weighs 6·7 pounds (though the standard buying and selling weight is 6·5 pounds), and therefore an actual gallon of petroleum is equivalent under a boiler to twelve pounds of coal, and 190 standard gallons are equal to a gross ton of coal. It is very easy with these data to determine the relative cost. At the wells, if the oil is worth say two cents a gallon, the cost is equivalent to $3.80 per ton for coal at the same place, while at say three cents per gallon, the lowest price at which it can be delivered in the vicinity of New York, it costs the same as coal at $5.70 per ton. The Standard Oil Co. estimate that 173 gallons are equal to a gross ton of coal, allowing for incidential savings, as in grate bars, carting ashes, attendance, &c.

Saw dust can be utilized for fuel to good advantage by a special furnace and automatic feeding devices. Spent tan bark is also used, mixed with some coal, or it may be burned without the coal in a proper furnace. Its value is about one-fourth that of the same weight of wood, as it comes from the press, but when dried its value is about 85 per cent. of the same weight of wood in same state of dryness.

Bagasse, the refuse of sugar cane, after being dried in the sun, is largely employed in Cuba. Its value is about equal to the same weight of pine wood, in the same state of dryness. As it comes from the mill it contains from 50 to 80 per cent. of water, in which state it may be burnt in Cook's Bagasse Furnace, under Babcock & Wilcox Boilers, with a result nearly or quite equal to that of the dried bagasse under ordinary boilers, thus saving the large expense of drying it.

It has been estimated that on an average one pound of coal is equal, for steam-making purposes, to 2 lbs. dry peat, 2¼ to 2½ lbs. dry wood, 2½ to 3 lbs. dried tanbark, 2½ to 3 lbs. sun-dried bagasse, 2¾ to 3 lbs. cotton stalks, 3¼ to 3¾ lbs. wheat or barley straw, 5 to 6 lbs. wet bagasse, and 6 to 8 pounds wet tan-bark.

Natural gas varies in quality, but is usually worth 2 to 2½ times the same *weight* of coal, or about 30,000 cubic feet are equal to a ton of coal.

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## TEMPERATURE OF FIRE.

By reference to the table of combustibles, it will be seen that the temperature of the fire is nearly the same for all kinds of combustibles, under similar conditions. If the temperature is known, the conditions of combustion may be inferred. The following table, from M. Pouillet, will enable the temperature to be judged by the appearance of the fire:

| Appearance. | Temp. Fah. | Appearance. | Temp. Fah. |
|---|---|---|---|
| Red, just visible . | 977° | Orange, deep.. | 2010 |
| " dull .... ... | 1290 | " clear. | 2190 |
| " Cherry, dull | 1470 | White heat .. | 2370 |
| " " full.. | 1650 | " bright .. | 2550 |
| " " clear | 1830 | " dazzling | 2730 |

To determine temperature by fusion of metals, etc.—

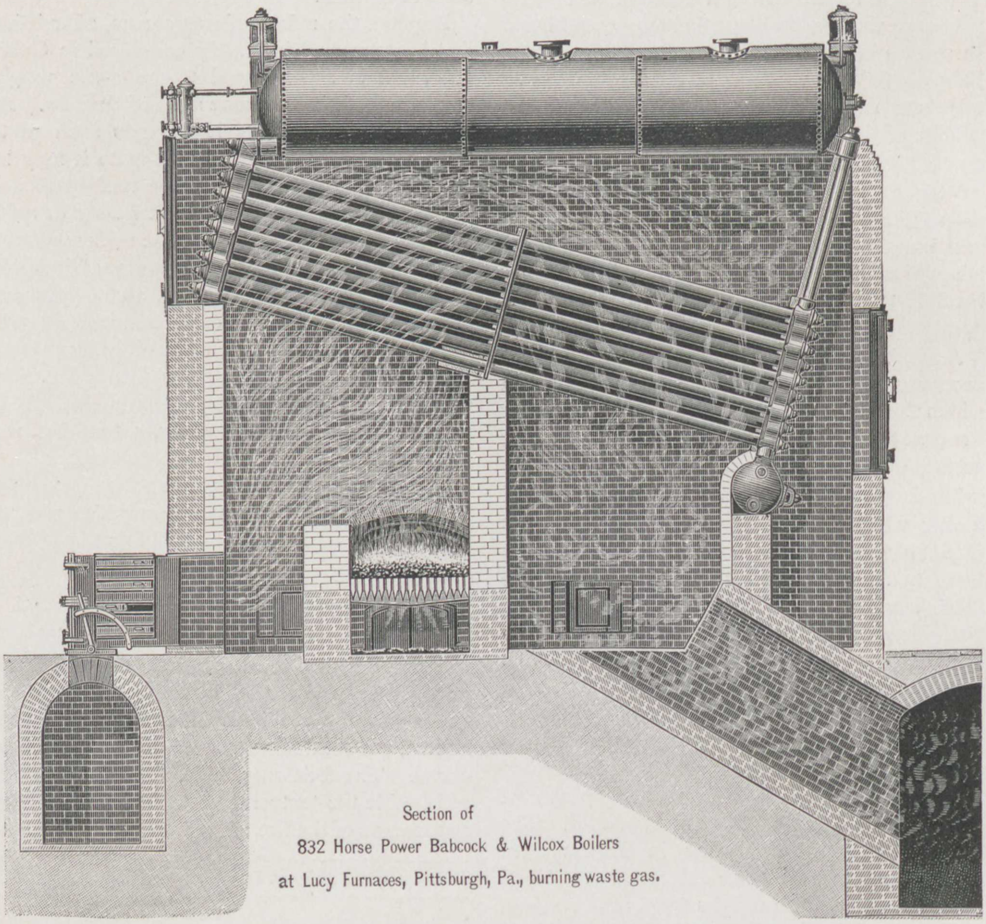
| Substance. | Temp. Fah. | Metal. | Temp. Fah. | Metal. | Temp. Fah. |
|---|---|---|---|---|---|
| Tallow..... | 92° | Bismuth.. | 518 | Silver, pure... | 1830 |
| Spermaceti . | 120 | Lead..... | 630 | Gold Coin .... | 2156 |
| Wax, white. | 154 | Zinc ..... | 793 | Iron Cast, med | 2010 |
| Sulphur .... | 239 | Antimony | 810 | Steel.......... | 2550 |
| Tin ......... | 455 | Brass... | 1650 | Wrought Iron | 2910 |

## BOILERS IN IRON AND STEEL WORKS.

The requirements of a steam boiler in an iron or steel works are more severe than in any other establishment, with possibly the exception of a sugar plantation. The heat applied to the boiler is not only intense, but fluctuating. The utmost possible amount of work may be required from the boiler for one hour, and scarcely any work the next, while in many iron works too little attention is paid to the boiler-house by the management, it being left to the care or neglect of incompetent men. There is, also, frequently a lack of sufficient boiler capacity, and in consequence the boilers are driven at a rate which is both wasteful of fuel and destructive to heating surfaces.

An extended experience with the Babcock & Wilcox boilers in iron and steel works extending over ten years, under a variety of conditions, in connection with heating, puddling and blast furnaces, utilizing the waste heat, has shown their adaptability and superiority for such work.

This boiler possesses for this purpose the advantages of safety and economy. The intense heat of the gases from a puddling furnace is very destructive of thick plates and riveted joints, causing frequent violent explosions in boilers so heated. The thin tubes, and rapid circulation, in these boilers render them less liable to damage from the high temperature, and the arrangement of heating surface secures a fuller absorption of the waste heat. Should a tube burn out, no serious explosion can occur.



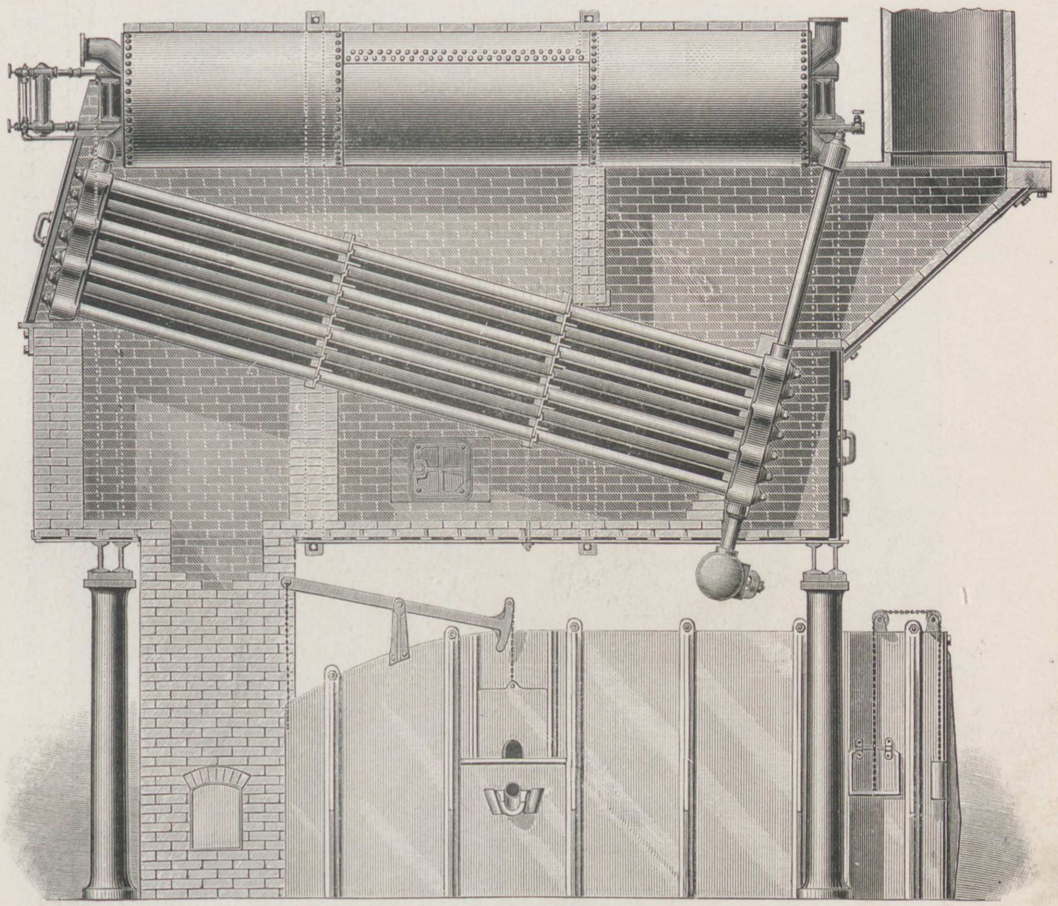
Section of
832 Horse Power Babcock & Wilcox Boilers
at Lucy Furnaces, Pittsburgh, Pa., burning waste gas.

Some establishments place their boilers over the furnaces, as shown in the cut, while others place them at the side of the furnace, or in the rear. One advantage of this boiler, especially for double puddling and large heating furnaces, is that a much larger amount of heating surface can be placed over a furnace than can be done with the boilers ordinarily used for this purpose, thereby giving greater economy of fuel with less cost of erection. At The Carron Iron Works, near Glasgow, Scotland, the Lucy Furnaces, Pittsburgh, Pa., and elsewhere, these boilers are fired with the waste gases of the blast furnaces with marked success. The combustion of the gas is perfect; the boilers develop much more than their rated capacity; and the dust contained in the gas has given no trouble. The manager of the Lucy Furnace says:

'They are very free steamers, easily cleaned, and will do a given amount of work on very much less gas than our cylinder or two-flue boilers. They have cost nothing for repairs.''

### WEIGHT AND VOLUME OF AIR.

A cubic foot of air at 60° and under average atmospheric pressure, at sea level, weighs 536 grains, and 13.06 cubic feet weigh one pound. Air expands or contracts an equal amount with each degree of variation in temperature. Its weight and volume at any temperature under 30 inches of barometer may be found within less than one-half of one per cent. by the following formula, in which W = weight in pounds of one cubic foot, V = volume in cubic feet, per pound,



Babcock & Wilcox Boilers over Puddling Furnace.

In rolling mills doing the heaviest and most irregular kind of work, the success of these boilers has been equally encouraging, and, in a number of the Bessemer Steel Works, they are supplying steam to reversing engines rolling steel ingots in two high trains, while several large plants supply power for rolling rods, bar iron, rails and beams, and drawing wire. The names of many extensive Iron and Steel Works, in some of which large plants have been in use for years, will be found in the list of references.

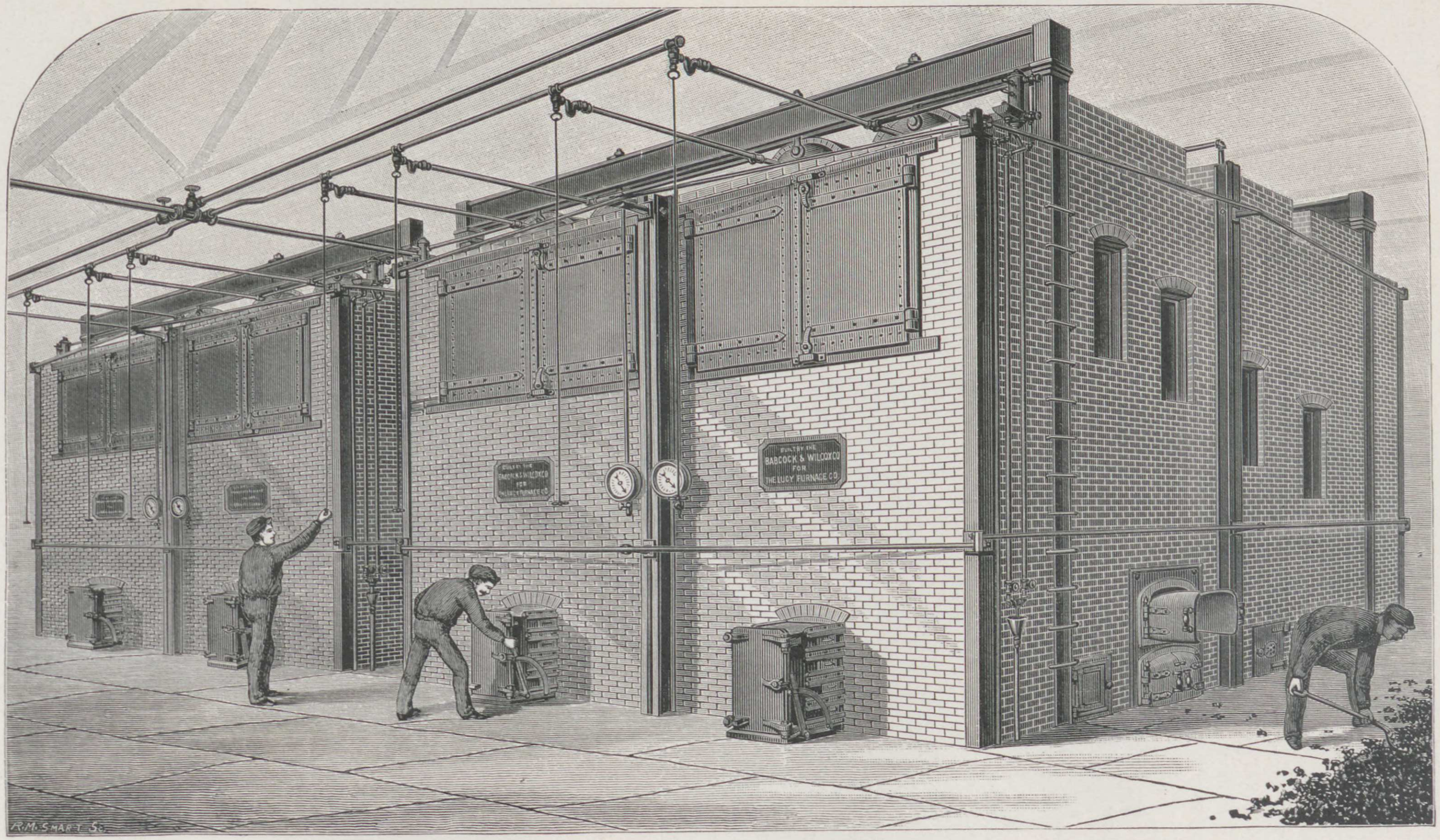
and $\tau$ = absolute temperature, or 460° added to that by the thermometer, $= t + 460$.

$$W = \frac{40}{\tau} \qquad V = \frac{\tau}{40}$$

For any condition of pressure and temperature the following formulas are very nearly exact:

$$W = 2.71\frac{p}{\tau} \quad . \quad . \quad V = \frac{\tau}{2.71p} \quad . \quad . \quad t = 2.71\,V p - 460$$

in which $p$ is pressure above absolute vacuum. The same formulæ answer for any other gas by changing the co-efficient.




Babcock & Wilcox Boilers, 832 H. P., at Lucy Furnace, Pittsburgh, Pa. Erected 1883. Fired with waste gases from blast furnaces.

### *HORSE-POWER OF BOILERS.*

Strictly speaking, there is no such thing as "horse-power" to a steam boiler; it is a measure applicable only to dynamic effect. But as boilers are necessary to drive steam-engines, the same measure applied to steam-engines has come to be universally applied to the boiler, and cannot well be discarded. In consequence, however, of the different quantity of steam necessary to produce a horse-power, with different engines, there has been great need of an accepted standard by which the amount of boiler required to provide steam for a commercial horse-power may be determined.

This standard, as fixed by Watt, was one cubic foot of water evaporated per hour from 212° for each horse-power. This was, at that time, the requirement of the best engine in use. At the present time, Prof. Thurston estimates, that the water required per hour, per horse-power, in good engines, is equal to the constant 200, divided by the square root of the pressure, and that in the best engines this constant is as low as 150. This would give for good engines, working with 64 lbs. pressure, 25 lbs. water, and for the best engines working with 100 lbs., only 15 lbs. water per hourly horse-power.

The extensive series of experiments, made under the direction of C. E. Emery, M. E., at the Novelty Works, in 1866-8, and published by Professor Trowbridge, show, that at ordinary pressures, and with good proportions, non-condensing engines of from 20 to 300 H. P., required only from 25 to 30 lbs. water per hourly horse-power, in regular practice.

The standard, therefore, adopted by the judges at the late Centennial Exhibition, of 30 lbs. water per hour, evaporated, at 70 lbs. pressure, from 100°, for each horse-power, is a fair one for both boilers and engines, and has been favorably received by the Am. Soc. of Mech. Engineers and by steam users, but as the same boiler may be made to do more or less work with less or greater economy, it should be also required that the rating of a boiler be based on the amount of water it will evaporate at a high economical rate.

For purposes of economy the amount of heating surface should never be less than one, and generally not more than two, square feet, for each 5,000 British thermal units to be absorbed per hour, though this depends somewhat on the character and location of such surface. The range given above is believed to be sufficient to allow for the different conditions in practice, though a far greater range is frequently employed. As, for instance, in torpedo boats, where everything is sacrificed to lightness and power, the heating surface is sometimes made to absorb 12,000 to 15,000 B. T. U. per square foot per hour, while in some mills, where the proprietor and his advisers have gone on the principle that "too much is just enough," a square foot is only required to absorb 1,000 units or less per hour. Neither extreme is good economy.

Square feet of heating surface is no criterion as between different styles of boilers—a square foot under some circumstances being many times as efficient as in others; but when an average rate of evaporation per square foot for any given boiler has been fixed upon by experiment, there is no more convenient way of rating the power of others of the same style. The following table gives an approximate list of square feet of heating surface per H. P. in different styles of boilers; and various other data for comparison:

| Type of Boiler. | Square feet of Heating Surface for One H. P. | Coal per sq. ft. H.S. per hour. | Relative Economy. | Relative Rapidity of Steaming. | Authority. |
|---|---|---|---|---|---|
| Water-tube ...... | 10 to 12 | .3 | 1.00 | 1.00 | Isherwood. |
| Tubular ......... | 14 to 18 | .25 | .91 | .50 | " |
| Flue... ......... | 8 to 12 | .4 | .79 | .25 | Prof. Trowbridge. |
| Plain Cylinder .. | 6 to 10 | .5 | .69 | .20 | |
| Locomotive. .... | 12 to 16 | .275 | .85 | .55 | |
| Vertical Tubular. | 15 to 20 | .25 | .80 | .60 | |

A horse-power in a steam-engine or other prime mover, is 550 lbs. raised 1 foot per second, or 33,000 lbs. 1 foot per minute.

### *HORSE-POWER OF DIFFERENT NATIONS.*

Most nations have a standard for power similar to, and generally derived from Watt's "horse-power," but owing to different standards of weights and measures, these are not identical, though the greatest differences amount to less than 1½ per cent. The following table gives the standard horse-power for each nation, in *kilogrammetres per second*, and in *foot-pounds per second*, expressed in the foot and pound standard in each country:

TABLE OF STANDARD HORSE-POWER FOR DIFFERENT NATIONS.

| Country. | Kilogrammetres per sec. | Baden Ft. pounds, per sec. | Saxon Ft. pounds, per sec. | Wortemberg Ft. pounds, per sec. | Prussian Ft. pounds, per sec. | Hanovarian Ft. pounds, per sec. | English Ft. pounds, per sec. | Austrian Ft. pounds, per sec. |
|---|---|---|---|---|---|---|---|---|
| France and Baden... | **75** | **500** | 529.68 | 521.58 | 477.93 | 513.53 | 542.47 | 423.68 |
| Saxony........ | 75.045 | 500.30 | **530.** | 523.89 | 478.22 | 513.84 | 542.80 | 423.93 |
| Wortemberg .. | 75.240 | 501.36 | 531.12 | **525.** | 479.23 | 514.92 | 543.95 | 424.83 |
| Prussia ....... | 75.325 | 502,17 | 531.97 | 525.85 | **480.** | 515.75 | 544.82 | 425.51 |
| Hanover...... | 75.361 | 502.41 | 532.23 | 526.10 | 480.23 | **516.** | 545.08 | 425.72 |
| England .. .. | 76.041 | 506.94 | 537.03 | 530.84 | 484.56 | 520.65 | **550.** | 429.56 |
| Austria ....... | 76.119 | 507.46 | 437.58 | 531.39 | 485.06 | 521.19 | 550.57 | **430.** |

## *CHIMNEYS.*

Chimneys are required for two purposes — 1st, to carry off obnoxious gases; 2d, to produce a draught, and so facilitate combustion. The first requires size, the second height.

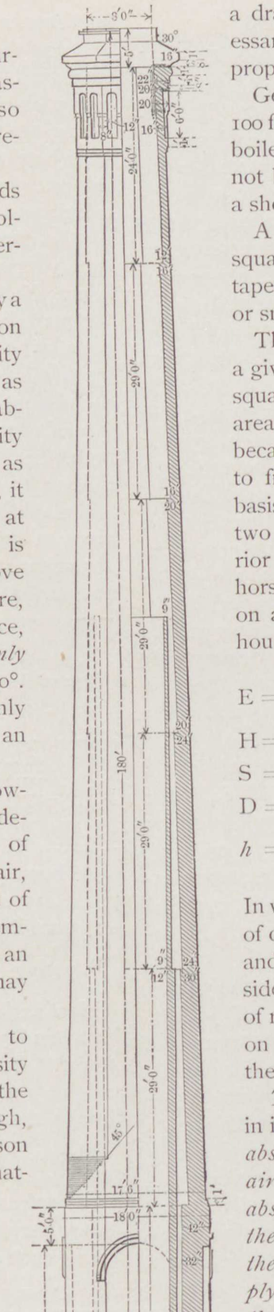
Each pound of coal burned yields from 13 to 30 pounds of gas, the volume of which varies with the temperature.

The weight of gas to be carried off by a chimney in a given time depends upon three things — size of chimney, velocity of flow, and density of gas. But as the density decreases directly as the absolute temperature, while the velocity increases, with a given height, nearly as the square root of the temperature, it follows that there is a temperature at which the weight of gas delivered is a maximum. This is about 550° above the surrounding air. Temperature, however, makes so little difference, that at 550° above, the quantity is *only four per cent.* greater than at 300°. Therefore, height and area are the only elements necessary to consider in an ordinary chimney.

The intensity of draught is, however, independent of the size, and depends upon the difference in weight of the outside and inside columns of air, which varies nearly as the product of the height into the difference of temperature. This is usually stated in an equivalent column of water, and may vary from 0 to possibly 2 inches.

After a height has been reached to produce draught of sufficient intensity to burn fine, hard coal, provided the area of the chimney is large enough, there seems no good mechanical reason for adding further to the height, whatever the size of the chimney required. Where cost is no consideration there is no objection to building as high as one pleases; but for the purely utilitarian purpose of steam making equally good results, might be attained with a shorter chimney at much less cost.

The intensity of draft required varies with the kind and condition of the fuel, and the thickness of the fires. Wood requires the least, and fine coal or slack the most. To burn anthracite slack to advantage,




a draught of 1¼ inch of water is necessary, which can be attained by a well-proportioned chimney 175 feet high.

Generally a much less height than 100 feet can not be recommended for a boiler, as the lower grades of fuel cannot be burned as they should be with a shorter chimney.

A round chimney is better than square, and a straight flue better than a tapering, though it may be either larger or smaller at top without detriment.

The effective area of a chimney for a given power, varies inversely as the square root of the height. The actual area, in practice, should be greater, because of retardation of velocity due to friction against the walls. On the basis that this is equal to a layer of air two inches thick over the whole interior surface, and that a commercial horse-power requires the consumption on an average of 5 pounds of coal per hour, we have the following formulæ :

$$E = \frac{0.3\,H}{\sqrt{h}} = A - 0.6\sqrt{A} \quad . \quad . \quad . \quad . \quad 1$$

$$H = 3.33\,E\sqrt{h} \quad . \quad . \quad . \quad . \quad 2$$

$$S = 12\sqrt{E} + 4 \quad . \quad . \quad . \quad . \quad 3$$

$$D = 13.54\sqrt{E} + 4 \quad . \quad . \quad . \quad . \quad 4$$

$$h = \left(\frac{0.3H}{E}\right)^2 \quad . \quad . \quad . \quad . \quad 5$$

In which H = horse-power; $h$ = height of chimney in feet; E = effective area, and A = actual area in square feet; S = side of square chimney, and D = dia. of round chimney in inches. The table on page is calculated by means of these formulæ.

*To find the draft* of a given chimney in inches of water: *Divide 7.6 by the absolute temperature of the external air* ($\tau_a = t + 460$); *divide 7.9 by the absolute temperature of the gases in the chimney* ($\tau_c = t' + 460$); *subtract the latter from the former, and multiply the remainder by the height of the chimney in feet.* This rule, expressed in a formula, would be:

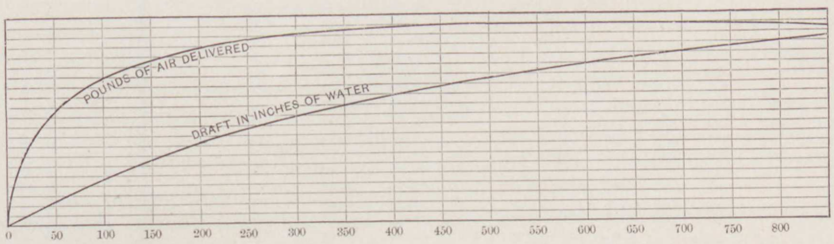
$$d = h\left(\frac{7.6}{\tau_a} - \frac{7.9}{\tau_c}\right).$$

*To find the height of a chimney,* to give a specific draft power, expressed in inches of water: *Proceed as above, through the first two steps, then divide the given draft power* *by the remainder*, the result is the height in feet. Or, by formula :

$$h = \frac{d}{\left(\frac{7.6}{\tau_a} - \frac{7.9}{\tau_c}\right)}$$

To find the maximum efficient draft for any given chimney, the heated column being 600 F., and the external air 62° : *Multiply the height above grate in feet by .007, and the product is the draft power in inches of water.*

DIAGRAM OF DRAFT AND CAPACITY OF CHIMNEY.



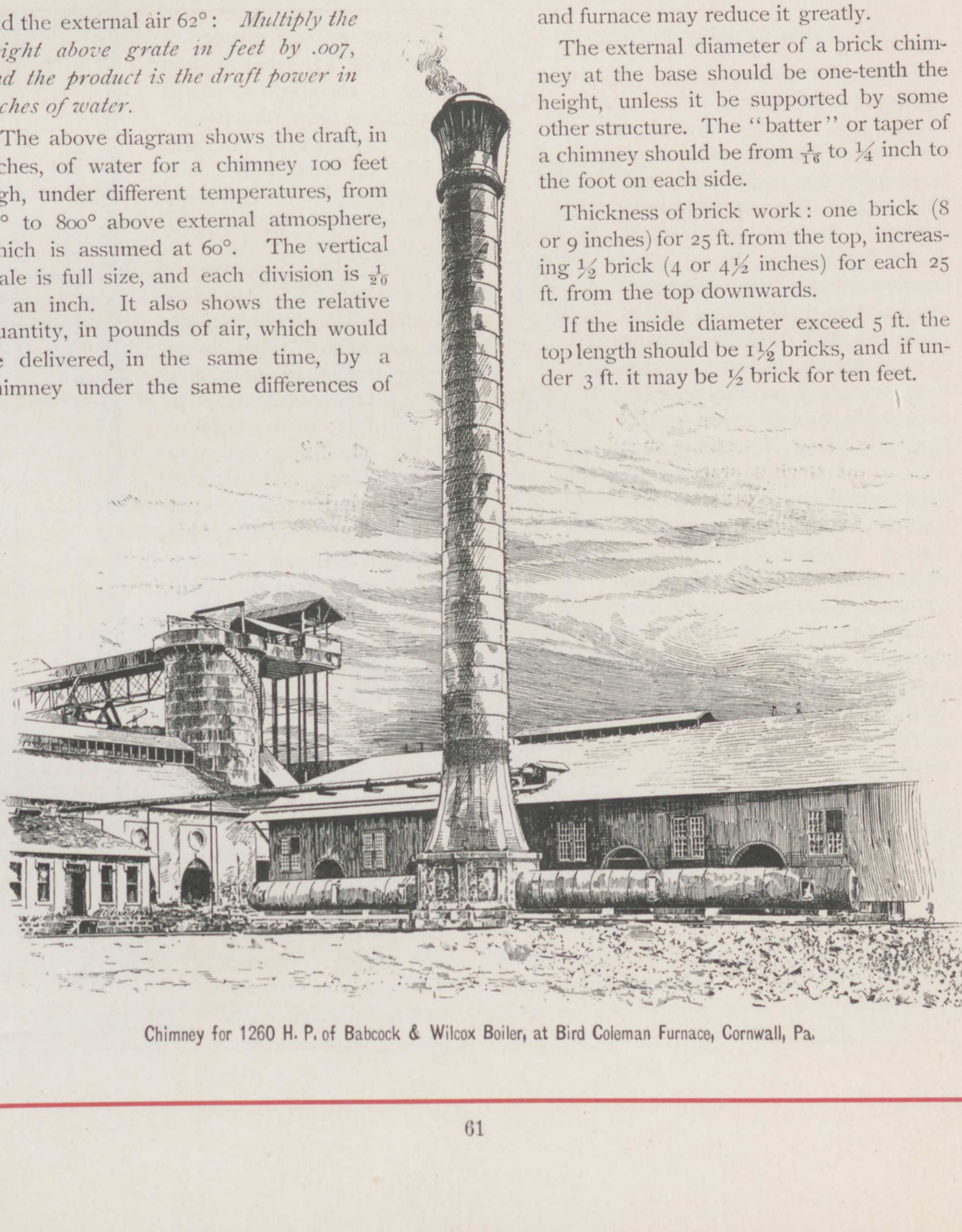

The above diagram shows the draft, in inches, of water for a chimney 100 feet high, under different temperatures, from 50° to 800° above external atmosphere, which is assumed at 60°. The vertical scale is full size, and each division is $\frac{1}{20}$ of an inch. It also shows the relative quantity, in pounds of air, which would be delivered, in the same time, by a chimney under the same differences of temperature. It will be seen that practically nothing can be gained by carrying the temperature of the chimney more than 350° above the external air at 60°.

*To determine the quantity of air*, in pounds, a given chimney will deliver per hour, multiply the distance in inches, at given temperature, on the diagram, by 1000 times the effective area in square feet, and by the square root of the height in feet. This gives a maximum. Friction in flues and furnace may reduce it greatly.

The external diameter of a brick chimney at the base should be one-tenth the height, unless it be supported by some other structure. The "batter" or taper of a chimney should be from $\frac{1}{16}$ to $\frac{1}{4}$ inch to the foot on each side.

Thickness of brick work : one brick (8 or 9 inches) for 25 ft. from the top, increasing ½ brick (4 or 4½ inches) for each 25 ft. from the top downwards.

If the inside diameter exceed 5 ft. the top length should be 1½ bricks, and if under 3 ft. it may be ½ brick for ten feet.



Chimney for 1260 H. P. of Babcock & Wilcox Boiler, at Bird Coleman Furnace, Cornwall, Pa.

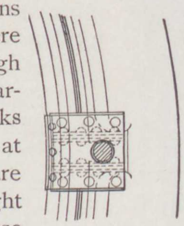
## SIZES OF CHIMNEYS WITH APPROPRIATE HORSE-POWER BOILERS.

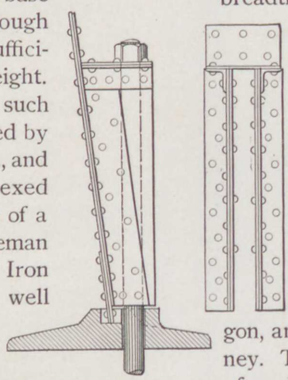
The following table has been computed by means of the formulæ on page 60, and will be found useful for ready reference:

| Dia. in inches. | Height of Chimneys. | | | | | | | | | | | Effective Area, square ft. | Actual Area, square ft. | Side of square of ap'roximate area. Inches. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 ft | 60 ft | 70 ft | 80 ft. | 90 ft. | 100 ft. | 110 ft. | 125 ft. | 150 ft. | 175 ft. | 200 ft. | | | |
| | Commercial Horse-Power. | | | | | | | | | | | | | |
| 18 | 23 | 25 | 27 | | | | | | | | | 0.97 | 1.77 | 16 |
| 21 | 35 | 38 | 41 | | | | | | | | | 1.47 | 2.41 | 19 |
| 24 | 49 | 54 | 58 | 62 | | | | | | | | 2.08 | 3.14 | 22 |
| 27 | 65 | 72 | 78 | 83 | | | | | | | | 2.78 | 3.98 | 24 |
| 30 | 84 | 92 | 100 | 107 | 113 | | | | | | | 3.58 | 4.91 | 27 |
| 33 | | 115 | 125 | 133 | 141 | | | | | | | 4.47 | 5.94 | 30 |
| 36 | | 141 | 152 | 163 | 173 | 182 | | | | | | 5.47 | 7.07 | 32 |
| 39 | | | 183 | 196 | 208 | 219 | | | | | | 6.57 | 8.30 | 35 |
| 42 | | | 216 | 231 | 245 | 258 | 271 | | | | | 7.76 | 9.62 | 38 |
| 48 | | | | 311 | 330 | 348 | 365 | 389 | | | | 10.44 | 12.57 | 43 |
| 54 | | | | 363 | 427 | 449 | 472 | 503 | 551 | | | 13.51 | 15.90 | 48 |
| 60 | | | | 505 | 539 | 565 | 593 | 632 | 692 | 748 | | 16.98 | 19.64 | 54 |
| 66 | | | | | 658 | 694 | 728 | 776 | 849 | 918 | 981 | 20.83 | 23.76 | 59 |
| 72 | | | | | 792 | 835 | 876 | 934 | 1023 | 1105 | 1181 | 25.08 | 28.27 | 64 |
| 78 | | | | | | 995 | 1038 | 1107 | 1212 | 1310 | 1400 | 29.73 | 33.18 | 70 |
| 84 | | | | | | 1163 | 1214 | 1294 | 1418 | 1531 | 1637 | 34.76 | 38.48 | 75 |
| 90 | | | | | | 1344 | 1415 | 1496 | 1639 | 1770 | 1893 | 40.19 | 44.18 | 80 |
| 96 | | | | | | 1537 | 1616 | 1720 | 1876 | 2027 | 2167 | 46.01 | 50.27 | 86 |

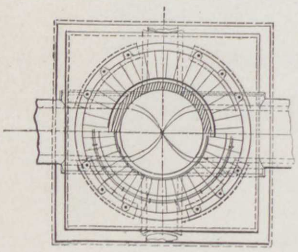
## *IRON CHIMNEY STACKS.*

In many places, notably in iron works, iron stacks are preferred to brick chimneys. Their efficiency for the same dimensions is somewhat higher because there is no infiltration of air as through brick-work. The cuts on the margin of this page show the stacks of the Pennsylvania Steel Co., at Sparrow's Point, Md. These are lined with brick their whole height and are bolted down to the base so as to require no stays, though in this case they would be sufficiently stable from their own weight. A good method of securing such bolts to the stack is practiced by the Pencoyd Iron-Works, Pa., and is shown in detail in the annexed figures. On page 61 is a cut of a similar stack, at the Bird Coleman Furnaces, Cornwall, Pa. Iron stacks require to be kept well painted to prevent rust, and generally, where not bolted down, as here shown, they need to be braced by rods or wires to surrounding objects. With four such braces attached to an angle iron ring at 2/3 the height of stack, and spreading laterally at least an equal distance, each brace should have an area in square inches equal to 1-1000 the exposed area of stack (dia. × height) in feet.





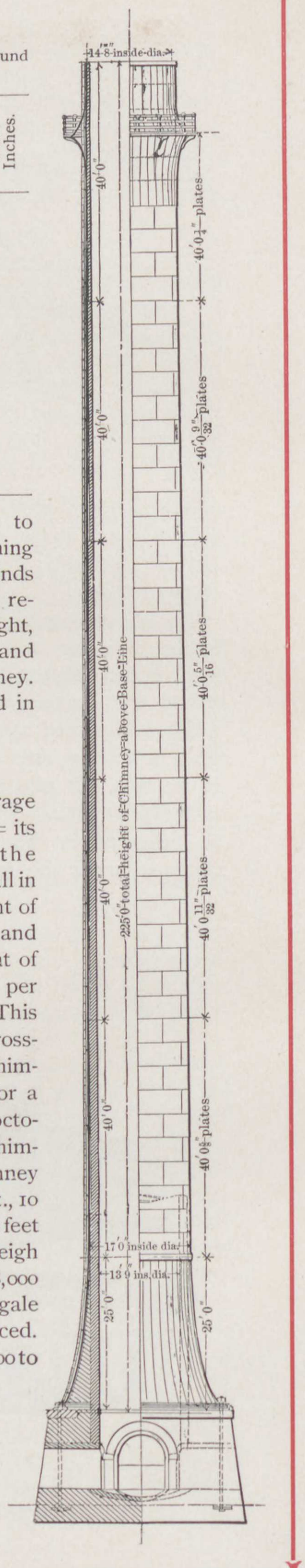
Holding down Bolts and Lugs, Pencoyd Iron Works.



STABILITY, or power to withstand the overturning force of the highest winds requires a proportionate relation between the weight, height, breadth of base, and exposed area of the chimney. This relation is expressed in the equation

$$C\frac{d\,h^2}{b} = W,$$

in which $d$ = the average breadth of the shaft, $h$ = its height; $b$ = the breadth of base; all in feet; $W$ = weight of chimney in lbs., and $C$ = a co-efficient of wind pressure per square foot of $a$. This varies with the cross-section of the chimney, and = 56 for a square, 35 for an octogon, and 28 for a round chimney. Thus a square chimney of average breadth of 8 ft., 10 feet wide at base and 100 feet high, would require to weigh $56 \times 8 \times 100 \times 10 = 448,000$ lbs. to withstand any gale likely to be experienced. Brick work weighs from 100 to 130 lbs. per cubic foot, hence such a chimney must average 13 inches thick to be safe. A round stack could weigh half as much, or have less base.



## *INCRUSTATION AND SCALE.*

Nearly all waters contain foreign substances in greater or less degree, and though this may be a small amount in each gallon, it becomes of importance where large quantities are evaporated. For instance, a 100 H. P. boiler evaporates 30,000 lbs. water in ten hours, or 390 *tons* per month; in the comparatively pure Croton water there would be 88 lbs. of solid matter in that quantity, and in many kinds of spring water as much as 2,000 lbs.

The nature and hardness of the scale formed of this matter will depend upon the kind of substances held in solution and suspension. Analyses of a great variety of incrustations show that carbonate and sulphate of lime form the larger part of all ordinary scale, that from carbonate being soft and granular, and that from sulphate hard and crystalline. Organic substances in connection with carbonate of lime, will also make a hard and troublesome scale.

The presence of scale or sediment in a boiler results in loss of fuel, burning and cracking of the boiler, predisposes to explosion, and leads to extensive repairs. It is estimated that the presence of $\frac{1}{16}$ inch of scale causes a loss of 13 per cent. of fuel, $\frac{1}{4}$ inch 38 per cent., and $\frac{1}{2}$ inch 60 per cent. The Railway Master Mechanics' Association of the U. S. estimates that the loss of fuel, extra repairs, etc., due to incrustation, amount to an average of $750 per annum for every locomotive in the Middle and Western States, and it must be nearly the same for the same power in stationary boilers.

The most common and important minerals in boiler scale are carbonate of lime, sulphate of lime, and carbonate of magnesia. Small amounts of alumina and silica are sometimes found, and an oxide of iron not infrequently is present as a coloring matter.

### *Means of Prevention.*

It is absolutely essential to the successful use of any boiler, except in pure water, that it be accessible for the removal of scale, for though a rapid circulation of water will delay the deposit, and certain chemicals will change its character, yet the most certain cure is periodical inspection and mechanical cleaning. This may, however, be rendered less frequently necessary, and the use of very bad water more practical by the employment of some preventives. The following are a fair sample of those in use, with their results:

M. Bidard's observations show that "anti-incrustators" containing organic matter help rather than hinder incrustations, and are therefore to be avoided.

Oak, hemlock, and other barks and woods, sumac, catechu, logwood, etc., are effective in waters containing carbonates of lime or magnesia, by reason of their tannic acid, but are injurious to the iron, and not to be recommended.

Molasses, cane juice, vinegar, fruits, distillery slops, etc., have been used with success so far as scale is concerned, by reason of the acetic acid which they contain, but this is even more injurious to the iron than tannic acid, while the organic matter forms a scale with sulphate of lime when it is present.

Milk of lime and metallic zinc have been used with success in waters charged with bicarbonate of lime, reducing the bicarbonate to the insoluble carbonate.

Barium chloride and milk of lime are said to be used with good effect at Krupp's Works, in Prussia, for waters impregnated with gypsum.

Soda ash and other alkalies are very useful in waters containing sulphate of lime, by converting it into a carbonate, and so forming a soft scale easily cleaned. But when used in excess they cause foaming, particularly where there is oil coming from the engine, with which they form soap. All soapy substances are objectionable for the same reason.

Petroleum has been much used of late years. It acts best in waters in which sulphate of lime predominates. As crude petroleum, however, sometimes helps in forming a very injurious crust, the refined only should be used.

Tannate of soda is a good preparation for general use, but in waters containing much sulphate, it should be supplemented by a portion of carbonate of soda or soda ash.

A decoction from the leaves of the eucalyptus is found to work well in some waters, in California.

For muddy water, particularly if it contain salts of lime, no preventive of incrustation will prevail except filtration, and in almost every instance the use of a filter, either alone or in connection with some means of precipitating the solid matter from solution, will be found very desirable.

In all cases where impure or hard waters are used, frequent "blowing" from the mud-drum is necessary to carry off the accumulated matter, which if allowed to remain would form scale.

When boilers are coated with a hard scale difficult to remove, it will be found that the addition of ¼ lb. caustic soda per horse-power, and steaming for some hours, according to the thickness of the scale, just before cleaning, will greatly facilitate that operation, rendering the scale soft and loose. This should be done, if possible, when the boilers are not otherwise in use.

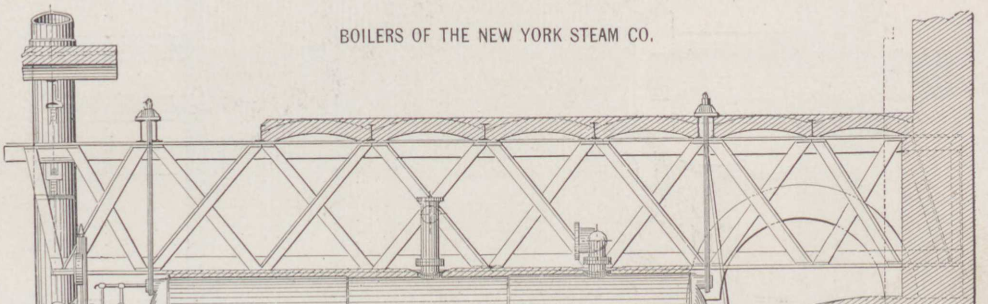
New York Steam Company's Station B, completed. Containing 16000 H. P. of Babcock & Wilcox Boilers.

### *HEATING FROM CENTRAL STATIONS.*

It has been thoroughly demonstrated, by practice, that a number of buildings may be heated from a single central plant, instead of its being necessary to place a boiler in each. This is a simple problem where the buildings form a group, as at Columbia College, in New York city, Cornell University, Ithaca, N. Y., Vanderbilt University, Nashville, Tenn., the Indiana State Asylums for the Insane, and many other similar institutions, where a single plant of Babcock & Wilcox Boilers supply heat and power to a number of detached buildings. It has also been attempted in a number of places to carry steam, as gas and water are supplied. Though a number of these attempts have been failures, the experience of the New York Steam Co., the most extensive of such plants yet constructed, has fully demonstrated that it is possible to thus carry steam for miles, with no serious losses, and that private houses and business places may be thus supplied regularly with steam, at reduced cost to them, and at a profit to the producer. This company have, at present, three stations in operation, one of which is doubtless the largest single plant of stationary boilers in the world, —12,000 H. P., under one roof,—supplying steam through seventeen miles of pipe, laid in the streets.

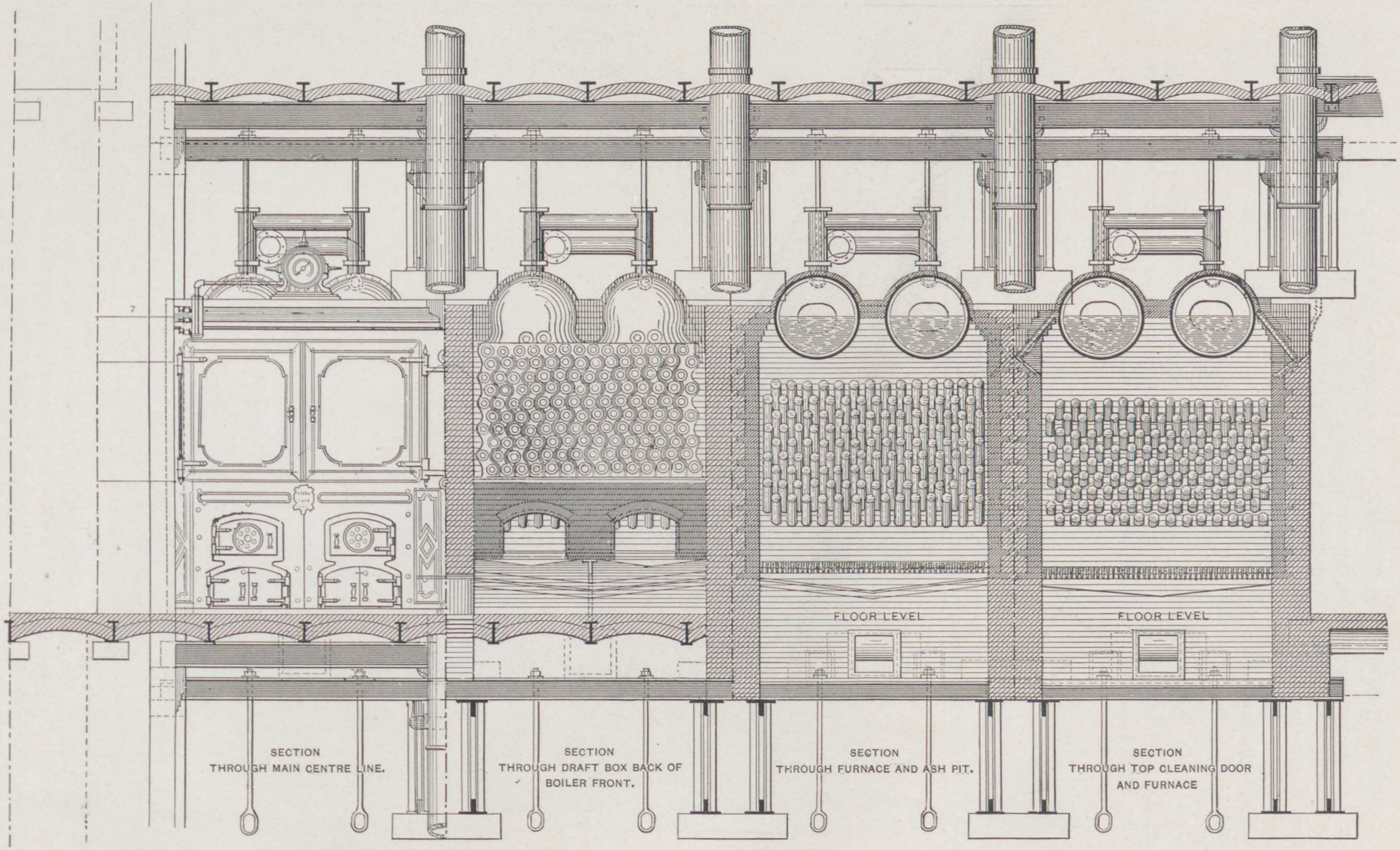
In a work of this magnitude it becomes absolutely imperative that the boilers which furnish the steam should be of such a construction as to give the greatest amount of useful effect for the coal burnt, and at the same time be able to run continuously, with a minimum amount of stoppage for repairs; and, above all, they should be so constructed as to be safe against destructive explosion. The ability to furnish dry steam is also a very important point, where it is intended to carry it through so many miles of pipe before it is finally used up. The boiler adopted was the Babcock & Wilcox Water-tube Boiler.

BOILERS OF THE NEW YORK STEAM CO.



Side Elevation showing section through boiler and flue.

NEW YORK STEAM HEATING COMPANY, STATION B. GREENWICH STREET, NEW YORK.




Front Elevation and partial section of one floor, showing Battery of four Boilers of 250 H. P. each, 12,500 H. P. now in use. Plan contemplates 4,000 H. P. more, or 16,000 H. P. in all.

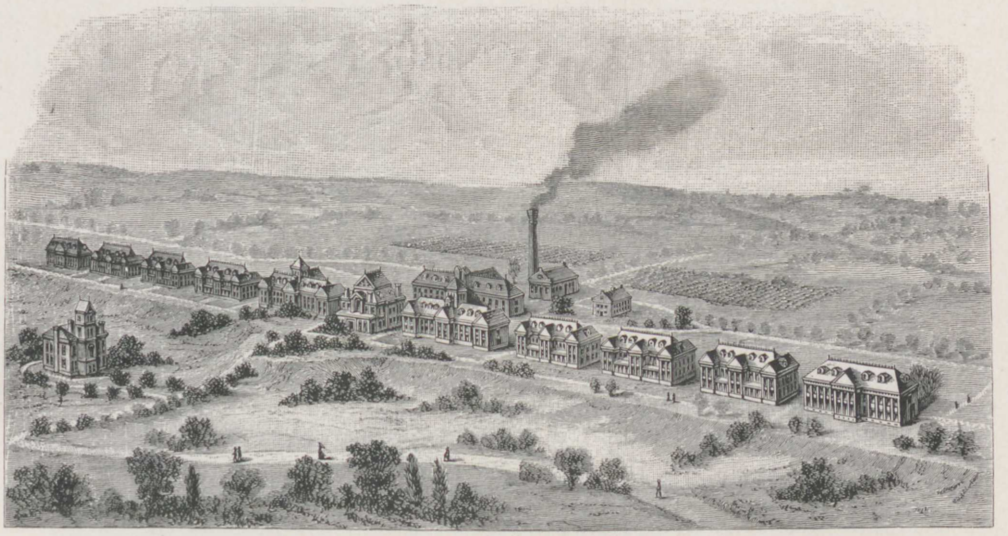
### HEATING BY STEAM.

In heating buildings by steam, the amount of boiler and heating pipe depends largely on the kind of building and its location. Wooden buildings require more than stone, and stone more than brick. Iron fronts require still more, and glass in windows demands twenty times as much heat as the same surface in brick walls. Also if the heating be done by indirect radiation from 50 to 100 per cent. more will be required than when direct radiation is used. No rules can be given which will not require a liberal application of "the coëfficient of common sense."

Radiating surface may be calculated by the rule: *Add together the square feet of glass in the windows, the number of cubic feet of air required to be changed per minute, and one-twentieth the surface of external wall and roof; multiply this sum by the difference between the required temperature of the room and that of the external air at its lowest point, and divide the product by the difference in temperature between the steam in the pipes and the required temperature of the room.* The quotient is the required radiating surface in square feet. Each square foot of radiating surface may be depended upon in average practice to give out three heat units per hour for each degree of difference in temperature between the steam inside and the air outside, the range under different conditions being about 50 per cent. above or below that figure. In *indirect* heating, the efficiency of the radiating surface will increase, and the temperature of the air will diminish, when the quantity of the air caused to pass through the coil increases. Thus one square foot radiating surface, with steam at 212°, has been found to heat 100 cubic feet of air per hour from zero to 150°, or 300 cubic feet from zero to 100° in the same time.

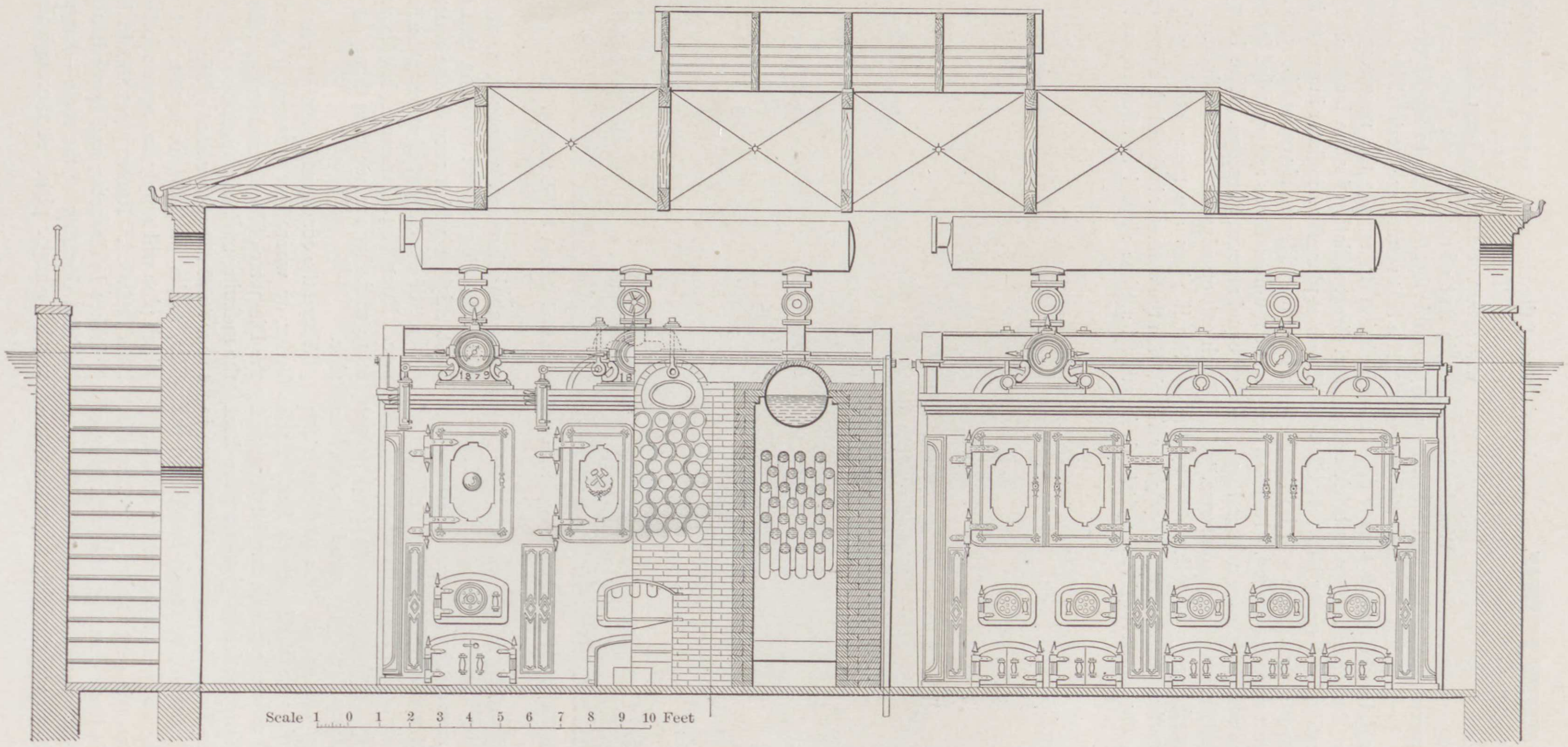
The best results are attained by using indirect radiation to supply the necessary ventilation, and direct radiation for the balance of the heat. The best place for a radiator in a room is beneath a window. Heated air cannot be made to enter a room unless means are provided for permitting an equal amount to escape. The best place for such exit openings is near the floor.

Small pipes are more effective than large. When the diameter is doubled, 20 per cent. additional surface should be allowed, and for three times the diameter, 30 per cent. additional is required. For indirect radiation that surface is most efficient which secures the most intimate contact of the current of air with the heated surface. Rooms on windward side of house require more radiating surface than those on sheltered side.



Northern Hospital for the Insane, Logansport Ind. with 400 H. P. of Babcock & Wilcox Boilers. Erected 1885.

Where the condensed water is returned to the boiler, or where low pressure of steam is used, the Diameter of Mains leading from the boiler to the radiating surface should be equal, in inches, to *one-tenth the square root of the radiating surface, mains included*, in square feet. Thus a 1-inch pipe will supply 100 square feet of surface, itself included. Return pipes should be at least ¾ inches in diameter, and never less than one-half the diameter of the main—longer returns requiring larger pipe. A thorough drainage of




Babcock & Wilcox Boilers, at Columbia College School of Mines, 400 H. P. 100 H. P., erected 1879; 250 H. P., erected 1882.

steam pipes will effectually prevent all cracking and pounding noises therein.

The amount of air required for ventilation is from 4 to 16 cubic feet per minute for each person, the larger amount being for prisons and hospitals. From ⅙ to 1 cubic foot per minute should be allowed for each lamp or gas burner employed.

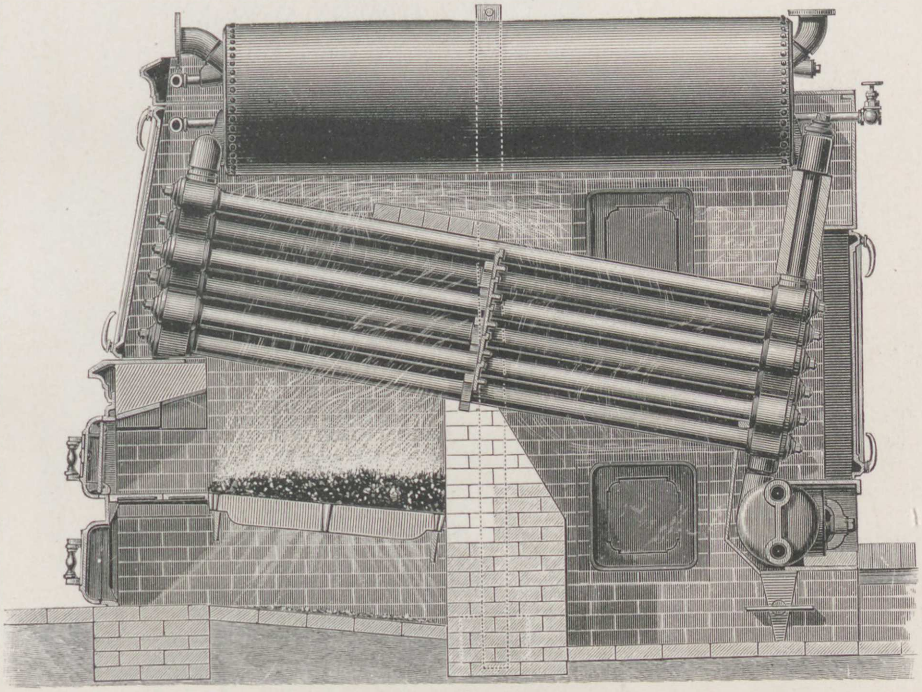
One square foot of Boiler Surface will supply from 7 to 10 square feet of radiating surface, depending upon the size of boiler and the efficiency of its surface, as well as that of the radiating surface. Small boilers for house use should be much larger proportionately than large plants. Each Horse-power of Boiler will supply from 240 to 360 feet of 1-inch steam pipe, or 80 to 120 square feet of radiating surface.

Cubic feet of space has little to do with amount of steam or surface required, but is a convenient factor for rough calculations. Under ordinary conditions one horse-power will heat, approximately, in

| | | | |
|---|---|---|---|
| Brick dwellings, in blocks, as in cities | 15,000 | to 20,000 | cub. ft. |
| " stores " " | 10,000 | " 15,000 | " " |
| " dwellings, exposed all round | 10,000 | " 15,000 | " " |
| " mills, shops, factories, etc. | 7,000 | " 10,000 | " " |
| Wooden dwellings, exposed, | 7,000 | " 10,000 | " " |
| Foundries and wooden shops, | 6,000 | " 10,000 | " " |
| Exhibition buildings, largely glass, etc. | 4,000 | " 15,000 | " " |

The system of heating mills and manufactories by means of pipes placed overhead, is being largely adopted, and is recommended by the Boston Manufacturers' Mutual Fire Ins. Co. in preference to radiators near the floor, particularly for rooms in which there are shafting and belting to circulate the air.

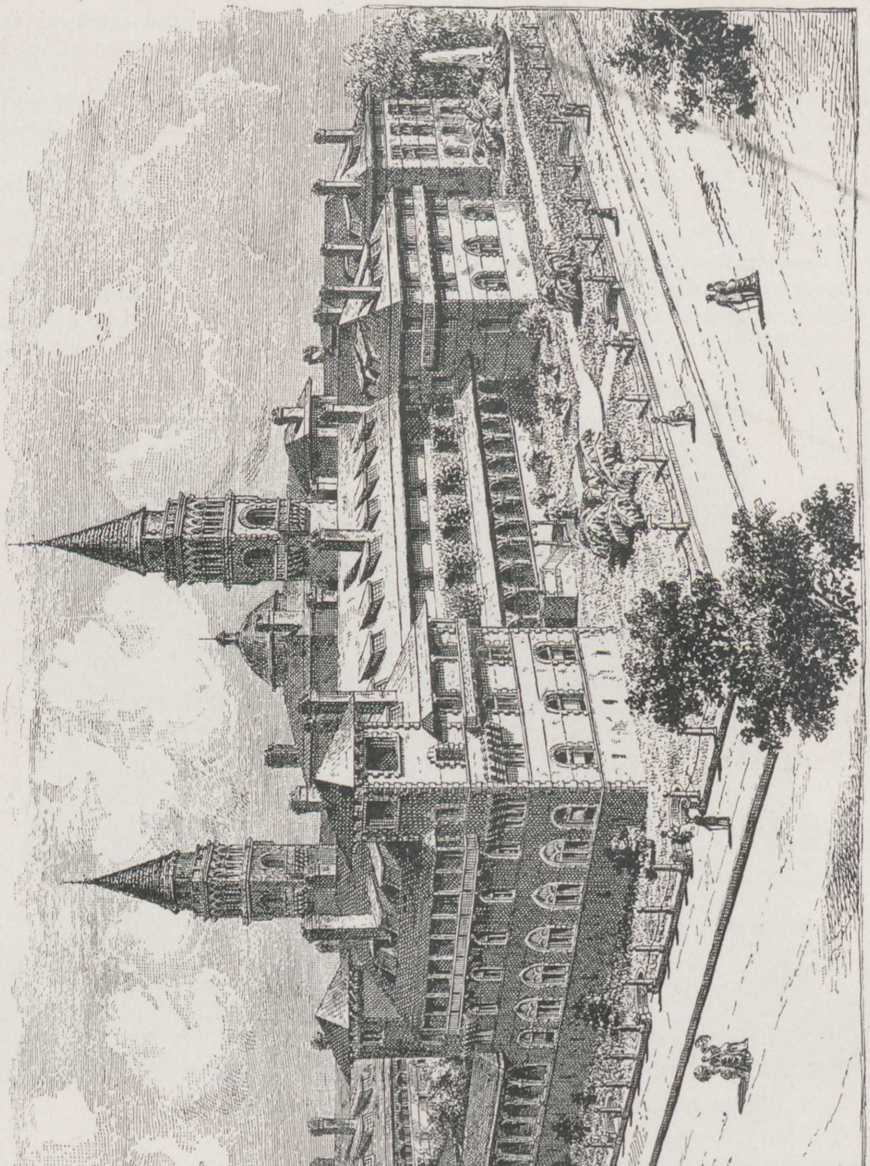
In heating buildings care should be taken to supply the necessary moisture to keep the air from becoming "dry" and uncomfortable. The capacity of air for moisture rises rapidly as it is heated, it being four times as great at 72° as at 32°. For comfort, air should be kept at about "50 per cent. saturated." This would require one pound of vapor to be added to each 2500 cubic feet heated from 32° to 70°.



Babcock & Wilcox Boiler, 35 H. P., Public School Building, Plainfield, N. J. Erected 1883.

A much needed attachment has recently been introduced, which acts automatically upon the steam valves of the radiators, or upon the hot air registers and ventilators, and maintains the temperature in a room to within one-half a degree of any standard desire.

A "separator" acting by centrifugal force has been recently tested, and is very efficient, in trapping out all the water entrained in steam. It will be found valuable, particularly where the steam has to be carried a long distance from the boiler, and for the purpose of preventing "hammering" of water in the pipes.

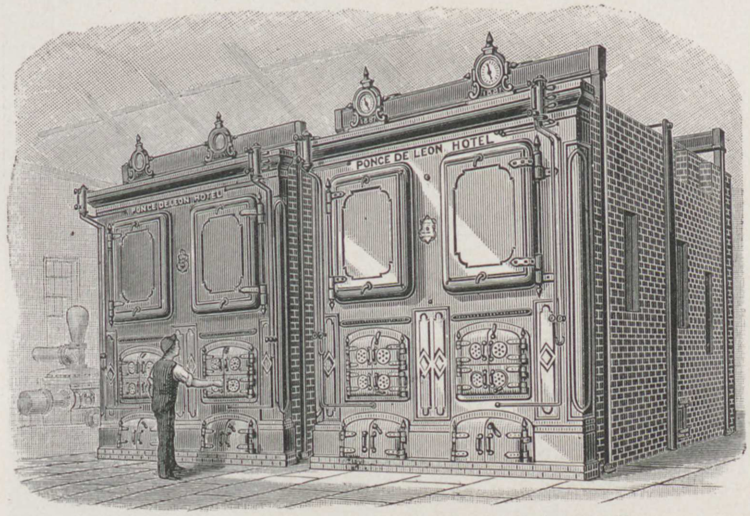


Hotel Ponce de Leon, St. Augustine, Fla. Heat and Power furnished by 416 H. P., Babcock & Wilcox Boilers.

### HEATING LIQUIDS AND BOILING BY STEAM.

(*a*). Efficiency of surface, where all the air is expelled. For vertical surface, each square foot will transmit 230 heat units per hour, for each degree of difference in the temperature of the two sides. For horizontal and inclined surface, each square foot will transmit 330 heat units per hour for each degree of difference in temperature between the two sides.

(*b*). Steam required. Each 966 heat units will require the condensation of one pound of steam at 212°, or 1,000 units at 75 lbs. pressure.




Babcock & Wilcox Boilers in Ponce de Leon Hotel, St. Augustine, Fla.

Each pound of steam condensed will evaporate one pound of water (nearly) from the temperature of evaporation. Each horse-power of boiler will heat 30,000 lbs. water 1° per hour, or evaporate 30 lbs. water in the same time.

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### DRYING BY STEAM.

There are three modes of drying by steam. 1st. By bringing wet substances in direct contact with steam-heated surfaces, as by passing cloth or paper over steam-heated cylinders, or clamping veneers between steam-heated plates. 2. By radiated heat from steam pipes, as in some lumber kilns, and laundry drying rooms. 3d. By causing steam-heated air to pass over wet surfaces, as in glue works, etc.

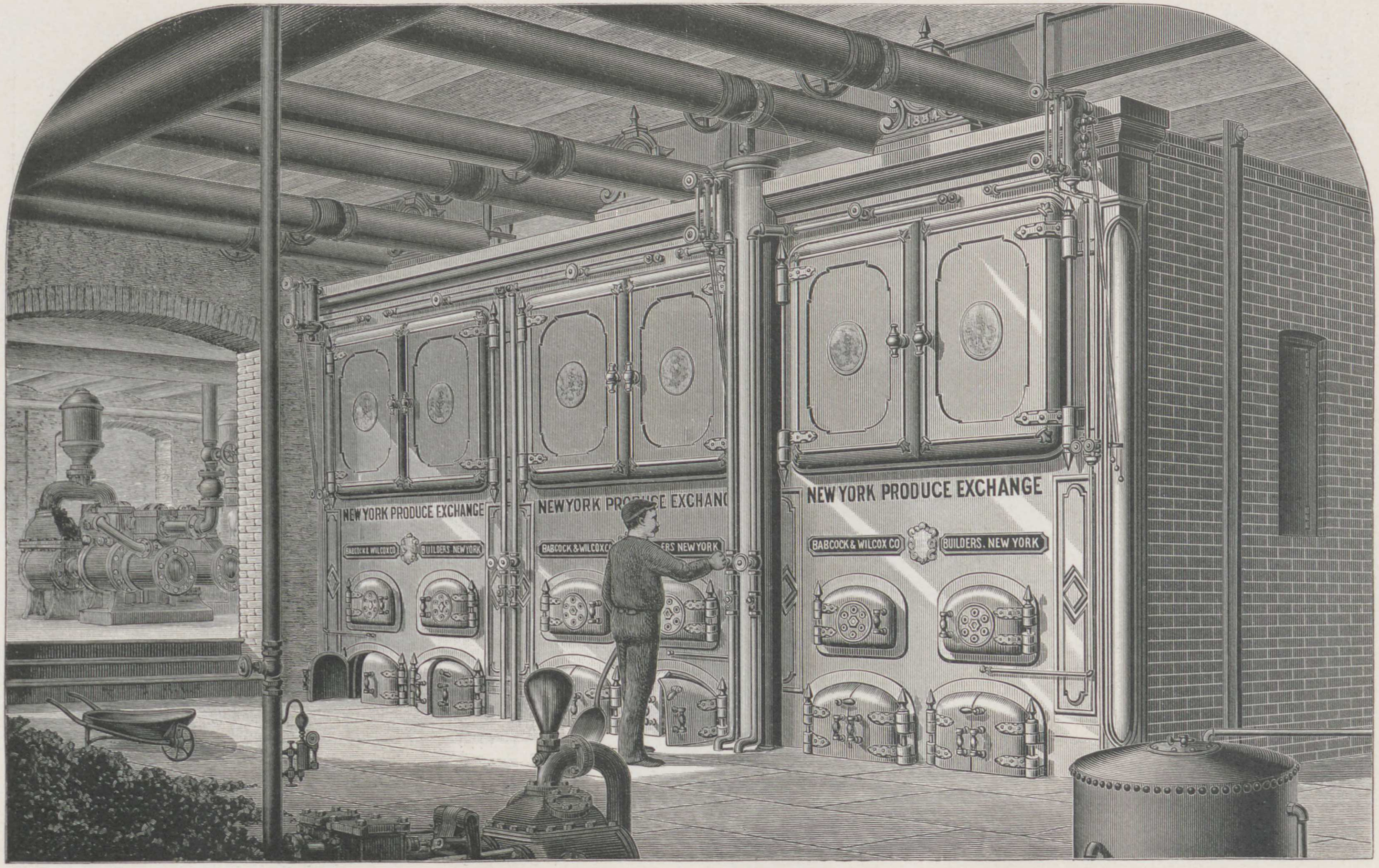
The second is rarely used except in combination with the third. The first is the most economical, the second less so, and the third least. Under favorable circumstances, it may be estimated that one horse-power of steam will evaporate 24 pounds water by the first method, 20 by the second, and 15 by the third.

The philosophy of drying or evaporating moisture by heated air rests upon the fact that the capacity of air for moisture is rapidly increased by rise in temperature. If air at 52° is heated to 72°, its capacity for moisture is doubled, and is four times what it was at 32°. The following table gives the weight of a saturated mixture of air and aqueous vapor at different temperatures up to 160°—the practical limit of heating air by steam, together with the weight of vapor, in pounds and per centage, and total heat, the portion contained in the vapor and the quantity of air required per pound of water.

By the inspection of this table it will be seen why it is more economical to dry at the higher temperatures. The atmosphere is seldom saturated with moisture, and in practice it will be found generally necessary to heat the air about 30° above the temperature of saturation. The best effect is produced where there is artificial ventilation, by fan or by chimney, and the course of the heated air is from above downwards.

#### SATURATED MIXTURES OF AIR AND AQUEOUS VAPOR.

| Temperature, degrees Fah. | Weight of 100 cub. ft. of mixture in lbs. | Weight of water in 100 cub. ft. of mixture in lbs. | Per cent. of water in mixture. | Heat Units in 100 cub. ft. of mixture. | Per cent. of heat in vapor. | Dry air required for vapor in mixture. lbs. | Dry air required for vapor in mixture. cub. ft. |
|---|---|---|---|---|---|---|---|
| 35 | 8.004 | 0.034 | 0.42 | 42.8 | 86.69 | 234.4 | 3080 |
| 40 | 7.920 | 0.041 | 0.52 | 59.8 | 76.59 | 192.2 | 2526 |
| 45 | 7.834 | 0.049 | 0.62 | 77.7 | 68.98 | 158.9 | 2088 |
| 50 | 7.752 | 0.059 | 0.76 | 97.6 | 66.29 | 130.4 | 1714 |
| 55 | 7.688 | 0.070 | 0.91 | 118.3 | 64.58 | 108.5 | 1326 |
| 60 | 7.589 | 0.082 | 1.08 | 140.1 | 64.31 | 91.6 | 1203 |
| 65 | 7.507 | 0.097 | 1.29 | 164.9 | 64.76 | 76.4 | 1004 |
| 70 | 7.425 | 0.114 | 1.49 | 189.7 | 66.21 | 66.0 | 868 |
| 75 | 7.342 | 0.134 | 1.79 | 221.6 | 66.74 | 55.0 | 723 |
| 80 | 7.262 | 0.156 | 2.15 | 253.6 | 68.02 | 45.6 | 599 |
| 85 | 7.178 | 0.182 | 2.54 | 289.7 | 69.66 | 38.4 | 505 |
| 90 | 7.108 | 0.212 | 2.98 | 330.2 | 71.19 | 32.5 | 427 |
| 95 | 7.009 | 0.245 | 3.50 | 373.4 | 72.87 | 27.6 | 363 |
| 100 | 6.924 | 0.283 | 4.08 | 422.0 | 74.58 | 23.5 | 308 |
| 105 | 6.830 | 0.325 | 4.76 | 474.7 | 76.22 | 20.0 | 263 |
| 110 | 6.741 | 0.373 | 5.23 | 533.9 | 77.88 | 17.1 | 224 |
| 115 | 6.650 | 0.426 | 6.41 | 599.1 | 79.52 | 14.6 | 192 |
| 120 | 6.551 | 0.488 | 7.46 | 672.4 | 81.14 | 12.6 | 163 |
| 125 | 6.454 | 0.554 | 8.55 | 750.5 | 82.62 | 10.7 | 140 |
| 130 | 6.347 | 0.630 | 9.90 | 839.4 | 84.13 | 9.1 | 118 |
| 135 | 6.238 | 0.714 | 11.44 | 936.7 | 85.57 | 7.7 | 102 |
| 140 | 6.131 | 0.806 | 13.14 | 1042.7 | 86.89 | 6.6 | 87 |
| 145 | 6.015 | 0.909 | 15.11 | 1160.6 | 88.18 | 5.6 | 74 |
| 150 | 5.891 | 1.022 | 17.33 | 1288.4 | 89.39 | 4.8 | 63 |
| 155 | 5.764 | 1.145 | 19.88 | 1427.4 | 90.53 | 4.0 | 53 |
| 160 | 5.679 | 1.333 | 23.47 | 1638.7 | 91.93 | 3.3 | 43 |




Batcock & Wilcox Boilers at the New York Produce Exchange, 624 H.P., erected February 1st, 1884.

### *FLOW OF STEAM THROUGH PIPES.*

The approximate weight of any fluid which will flow in one minute through any given pipe with a given head or pressure may be found by the following formula:

$$W = 300\sqrt{\frac{D\,(p_1 - p_2)\,d^5}{L\left(1 + \frac{3.6}{d}\right)}}$$

in which $W$ = weight in pounds avoirdupois, $d$ = diameter in inches, $D$ = density or weight per cubic foot; $p_1$ the initial pressure, $p_2$ pressure at end of pipe, and $L$ = the length in feet.

The following table gives, approximately, the weight of steam per minute which will flow from various initial pressures, with one pound loss of pressure through straight smooth pipes, each having a length of 240 times its own diameter.

For sizes of pipe below 6-inch, the flow is calculated from the *actual* areas of "standard" pipe of such nominal diameters.

The resistance at an elbow is equal to ⅔ that of a globe valve. These equivalents—for opening, for elbows, and for valves,—must be added in each instance to the actual length of pipe. Thus a 4-in. pipe, 120 diameters (40 feet) long, with a globe valve and three elbows, would be equivalent to $120 + 60 + 60 + (3 \times 40) = 360$ diameters long; and $360 \div 240 = 1\frac{1}{2}$. It would therefore have 1½ lbs. loss of pressure at the flow given in the table, or deliver ($1 \div \sqrt{1\frac{1}{2}} = .816$), 81.6 per cent. of the steam with the same (1 lb.) loss of pressure.

### *FLOW OF STEAM FROM A GIVEN ORIFICE.*

Steam of any pressure flowing through an opening into any other pressure, less than three-fifths of the initial, has practically a constant velocity, 888 feet per second, or a little over ten miles per minute; hence the amount discharged in pounds is proportionate to the weight or density of the steam. To ascertain the pounds, avoirdupois, discharged per minute, *multiply the area of opening in inches, by 370 times the weight per cubic foot of the steam.* (See p. 49 .)

Or the quantity discharged, per minute, may be approximately found by Rankine's formula: $W = 6\,a\,p \div 7$ in which $W$ = weight in pounds, $a$ = area, in square inches, and $p$ = absolute pressure. The theoretical flow requires to be multiplied by $k = 0.93$, for a short pipe, or 0.63 for a thin opening, as in a plate, or a safety valve.

Where the steam flows into a pressure more than ⅔ the pressure in the boiler:

$W = 1.9\,a\,k\,\sqrt{(p - \delta)\,\delta}$; in which $\delta$ = difference in pressure between the two sides, in pounds per square inch, and $a$, $p$ and $k$ as above.

To reduce to horse-power, multiply by 2.

Where a given horse-power is required to flow through a given opening, to determine the necessary difference in pressure:

$$\delta = \frac{p}{2} - \sqrt{\frac{p^2}{4} - \frac{\text{H.P.}^2}{14a^2\,k}}$$

#### TABLE OF FLOW OF STEAM THROUGH PIPES.

| Initial pressure by gauge, lbs. per sq. in. | Diameter of Pipe in inches. Length of each = 240 diameters. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ¾ | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 15 | 18 |
| | Weight of Steam per minute in pounds, with one pound loss of pressure. | | | | | | | | | | | | | |
| 1 | 1.16 | 2.07 | 5.7 | 10.27 | 15.45 | 25.38 | 46.85 | 77.3 | 115.9 | 211.4 | 341.1 | 502.4 | 804 | 1177 |
| 10 | 1.44 | 2.57 | 7.1 | 12.72 | 19.15 | 31.45 | 58.05 | 95.8 | 143.6 | 262.0 | 422.7 | 622.5 | 996 | 1458 |
| 20 | 1.70 | 3.02 | 8.3 | 14.94 | 22.49 | 36.94 | 68.20 | 112.6 | 168.7 | 307.8 | 496.5 | 731.3 | 1170 | 1713 |
| 30 | 1.91 | 3.40 | 9.4 | 16.84 | 25.35 | 41.63 | 76.84 | 126.9 | 190.1 | 346.8 | 559.5 | 824.1 | 1318 | 1930 |
| 40 | 2.10 | 3.74 | 10.3 | 18.51 | 27.87 | 45.77 | 84.49 | 139.5 | 209.0 | 381.3 | 615.3 | 906.0 | 1450 | 2122 |
| 50 | 2.27 | 4.04 | 11.2 | 20.01 | 30.13 | 49.48 | 91.34 | 150.8 | 226.0 | 412.2 | 665.0 | 979.5 | 1567 | 2294 |
| 60 | 2.43 | 4.32 | 11.9 | 21.38 | 32.19 | 52.87 | 97.60 | 161.1 | 241.5 | 440.5 | 710.6 | 1046.7 | 1675 | 2451 |
| 70 | 2.57 | 4.58 | 12.6 | 22.65 | 34.10 | 56.00 | 103.37 | 170.7 | 255.8 | 466.5 | 752.7 | 1108.5 | 1774 | 2596 |
| 80 | 2.71 | 4.82 | 13.3 | 23.82 | 35.87 | 58.91 | 108.74 | 179.5 | 269.0 | 490.7 | 791.7 | 1166.1 | 1866 | 2731 |
| 90 | 2.83 | 5.04 | 13.9 | 24.92 | 37.52 | 61.62 | 113.74 | 187.8 | 281.4 | 513.3 | 828.1 | 1219.8 | 1951 | 2856 |
| 100 | 2.95 | 5.25 | 14.5 | 25.96 | 39.07 | 64.18 | 118.47 | 195.6 | 293.1 | 534.6 | 862.6 | 1270.1 | 2032 | 2975 |
| 120 | 3.16 | 5.63 | 15.5 | 27.85 | 41.93 | 68.87 | 127.12 | 209.9 | 314.5 | 573.7 | 925.6 | 1363.3 | 2181 | 3193 |
| 150 | 3.45 | 6.14 | 17.0 | 30.37 | 45.72 | 75.09 | 138.61 | 228.8 | 343.0 | 625.5 | 1009.2 | 1486.5 | 2378 | 3481 |

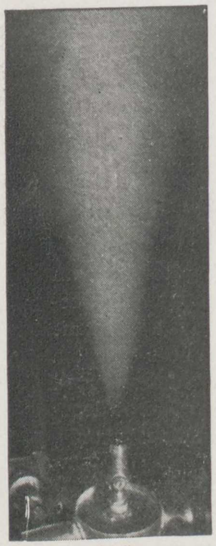
For horse-power, multiply the figures in the table by 2. For any other loss of pressure, multiply by the square root of the given loss. For any other length of pipe, *divide 240 by the given length expressed in diameters, and multiply the figures in the table by the square root of this quotient*, which will give the flow for 1 lb. loss of pressure. Conversely dividing the given length by 240 will give the loss of pressure for the flow given in the table.

The loss of head due to getting up the velocity, to the friction of the steam entering the pipe, and passing elbows and valves, will reduce the flow given in the tables. The resistance at the opening, and that at a globe valve, are each about the same as that for a length of pipe equal to 114 diameters divided by a number represented by $1 + (3.6 \div \text{diameter})$. For the sizes of pipes given in the table, these corresponding lengths are:

| ¾ | 1 | 1½ | 2 | 2½ | 3 | 4 | 5 | 6 | 8 | 10 | 12 | 15 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 25 | 34 | 41 | 47 | 52 | 60 | 66 | 71 | 79 | 84 | 88 | 92 | 95 |

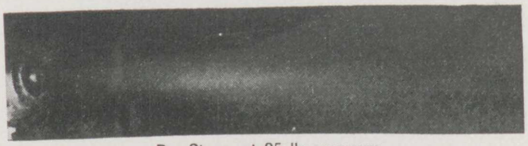
## PRIMING OR WET STEAM.

A fault, frequently met with in steam boilers is the carrying over of water mechanically mixed with the steam, which water not only carries away heat without any useful effect, but, when present in any marked quantity itself becomes a source of danger and of serious loss in the engine. This is a point frequently forgotten in designing boilers, particularly sectional boilers. If steam rises from a surface of water faster than about 2 ft. 6 ins. to 3 ft. per second, it carries water with it in the form of spray, and when a fine spray is once formed in steam it does not readily settle against a rising current of very low velocity, as a current of 1 ft. per second will carry with it a globule of water $\frac{1}{1000}$ of an inch in dia.

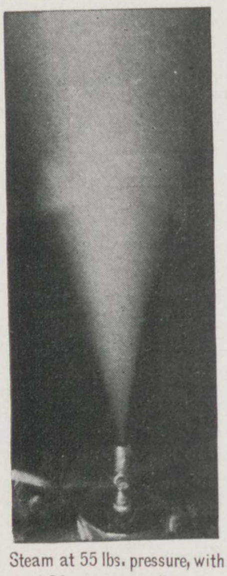


Steam at 95 lbs. pressure Superheated 9 degrees.

The common method of determining the percentage of moisture in steam is described in the report of the test of Babcock & Wilcox boilers at the Raritan Woolen Mill, on a subsequent page. If experiments of this kind are not made with great care by experienced hands, and with instruments of the utmost accuracy, they are liable to such errors as will render them worthless. Fuller directions for this purpose, together with a statement of the difficulties in securing accuracy in such tests, will be found in the report of the Com. on Boiler Tests, in Vol. VI, of the Transactions of the Amer. Society of Mechanical Engineers.



Dry Steam at 95 lbs. pressure.

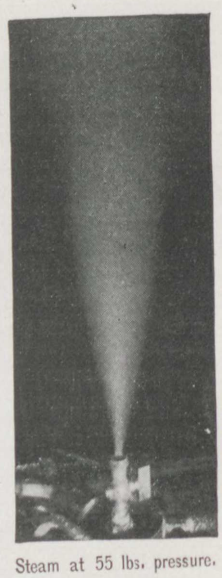


Steam at 55 lbs. pressure, with 1.94 per cent. moisture.

Another method, in which the heat required to evaporate the entrained water, has been invented, and used with excellent results, by Geo. H. Barrus, M. E.

PROF. J. E. DENTON has demonstrated that jets of steam escaping from an orifice in a boiler or steam reservoir show unmistakable change of appearance to the eye when the steam varies less than one per cent. from the condition of saturation either in the direction of wetness or superheating. Consequently if a jet of steam flow from a boiler into the atmosphere under circumstances such that very little loss of heat occurs through radiation, etc., and the jet be transparent close to the orifice, or be even a grayish white color, the steam may be assumed to be so nearly dry that no portable condensing calorimeter will be capable of measuring the amount of water therein. If the jet be strongly white, the amount of water may be roughly judged up to about 2 per cent. but beyond this a calorimeter only can determine the exact amount of moisture. The cuts on this page were made direct by photography from jets under conditions stated, and show very clearly the effect of dryness and slight moisture on such jets. With a little experience any one may determine by this method the conditions of steam within the above limits. A common brass pet cock may be used as an orifice, but it should, if possible, be set into the steam drum of the boiler and never be placed further away from the latter than four feet, and then only when the intermediate reservoir or pipe is well covered, for a very short travel of dry steam through a naked pipe, will cause it to become perceptibly moist. Steam containing not more than 3 per cent. moisture may be termed commercially "dry."

Steam at 55 lbs. pressure with 1.4 per cent. moisture.



Steam at 55 lbs. pressure. Boiler Foaming Violently.

Many boilers show a high apparent evaporation in consequence of furnishing "wet steam," while practically they are anything but economical. Parties have been known to claim an evaporation of 19 to 20 pounds per pound of coal, where the highest practically possible is not over 13. Such boilers are dear at any price.

The cause of priming may be either impure water, too much water, or improper proportions in the boiler. When a boiler is found to form wet steam with good water, carried at a proper height, it is a proof of wrong design.

The amount of priming in different boilers varies greatly, and as yet there is not sufficient data to establish any definite ratio for boilers in ordinary use. The experiments of M. Hirn, at Mulhouse, showed an average of at least 5 per cent.; Zeuner sets it down as approximately from 7½ to 15 per cent.; the careful experiments at the American Institute in 1871 show in cylindrical tubulars 7.9 per cent., and in the tests at the Centennial Exposition one boiler showed as high as 18.57 per cent. priming.

In sixteen different tests of the dryness of the steam from Babcock & Wilcox boilers made by twelve different engineers, the average moisture in the steam was only 1.116 per cent. The highest was 4.16 per cent., which was less than the same engineer with the same apparatus found in large two-flue boilers, working very lightly.

## SUPERHEATED STEAM.

Steam which has a higher temperature than that normal to its pressure, is termed "superheated" or "gaseous." Dr. Seimens found that when steam at 212° was heated separate from water it increased rapidly in volume up to 230°, after which it expanded uniformly as a permanent gas. If this superheating could be carried to such an extent as to avoid the "initial condensation" within the cylinder of an engine, there would be a marked economy in its use, but this involves so high a temperature as to burn the lubricating material and destroy the engine in a short time. Dixwell found superheating so as to maintain in the cylinder a temperature of 400° with steam at a pressure of 70 lbs., to be the limit of possible lubrication. With a higher pressure that degree of superheating would not afford sufficient additional heat for the purpose. The present tendency to high pressures seems, therefore, to preclude the possibility of much gain through superheating, because the temperatures are already carried to very nearly the limit at which lubrication can be maintained. For other purposes the use of superheated steam adds little if anything to the economy, while it greatly increases the cost and the wear and tear. Where superheating is required it should always be done by a separate apparatus, and pains must be taken to separate the entrained water from the steam before it enters the superheater. The use in any steam boiler of superheating surface exposed to the gases of combustion, is highly objectionable and is of doubtful efficiency. Attempts to superheat steam by means of the waste gases, are usually failures because in a well proportioned boiler the low temperature of such gases necessitates an unreasonably large surface to produce the desired effect. Steam cannot be superheated when it is in contact with water.

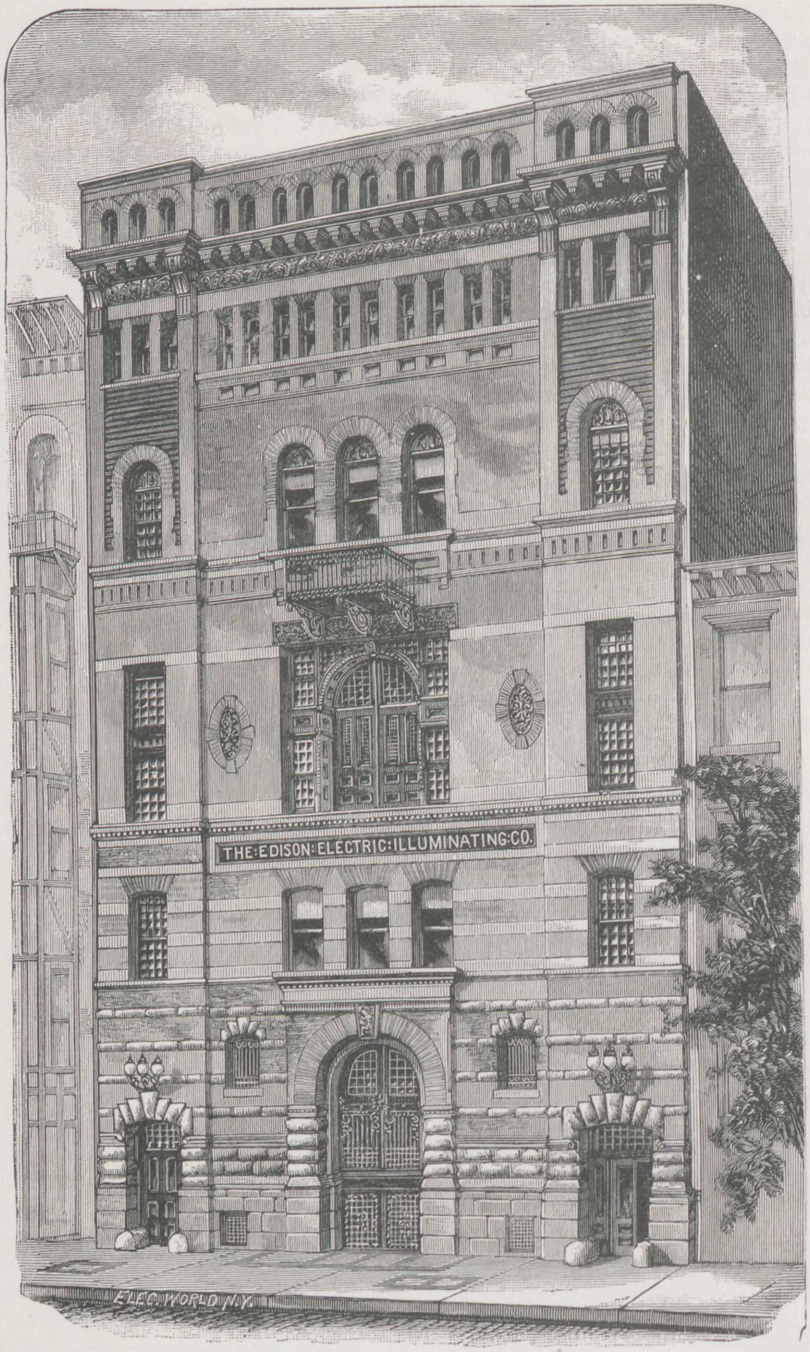
## FEEDING BOILERS.

The relative value of injectors, direct-acting steam pumps, and pumps driven from the engine, is a question of importance to all steam users. The following table has been calculated by D. S. Jacobus, M. E., from data obtained by experiment. It will be noticed that when feeding cold water direct to boilers, the injector has a slight economy, but when feeding through a heater a pump is much the most economical.

| Method of Supplying Feed Water to Boiler. Temperature of feed water as delivered to the pump or to the injector, 60° Fah. Rate of evaporation of boiler, 10 pounds of water per pound of coal from and at 212° Fah. | Relative amount of coal required per unit of time, the amount for a direct acting pump, feeding water at 60°, without a heater, being taken as unity. | Saving of fuel over the amount required when the boiler is fed by a direct acting pump without heater |
|---|---|---|
| Direct acting pump, feeding water at 60°, without a heater.......... ........ | 1.000 | .0 |
| Injector feeding water at 150°, without a heater.......... | .985 | 1.5 per ct. |
| Injector feeding through a heater in which the water is heated from 150 to 200°..... | .938 | 6.2 " |
| Direct acting pump feeding water through a heater, in which it is heated from 60 to 200°.................... | .879 | 12.1 " |
| Geared pump, run from the the engine, feeding water through a heater, in which it is heated from 60 to 200°.. | .868 | 13.2 " |

## ECONOMY OF HIGH PRESSURE STEAM.

Higher steam pressure is the tendency of the times, and with good reason, for the higher the pressure the greater the opportunity for economy in generating power. The compound and triple expansion engines of the present day, which have reduced the cost of power some 40 per cent. over the best performance of a few years ago, require higher pressure than can with safety be carried on shell boilers, but there is no difficulty in carrying any desirable pressure on a sectional water-tube boiler properly constructed. Babcock & Wilcox boilers in special cases, carry as high as 500 lbs. pressure in regular work.




Edison Central Station, W. 26th St., New York City.

To contain 3000 Horse-power Babcock & Wilcox Boilers, when in full running order; 900 H. P. now in use, erected 1888.

### COVERING FOR BOILERS, STEAM PIPES, ETC.

The losses by radiation from unclothed pipes and vessels containing steam is considerable, and in the case of pipes leading to steam engines, is magnified by the action of the condensed water in the cylinder. It therefore is important that such pipes should be well protected. The following table gives the loss of heat from steam pipes, naked and clothed with wool or hair felt, of different thickness, the steam pressure being assumed at 75 lbs. and the extreme air at 60°.

There is a wide difference in the value of different substances for protection from radiation, their value varying nearly in the inverse ratio of their conducting power for heat, up to their ability to transmit as much heat as the surface of the pipe will radiate, after which they become detrimental, rather than useful, as covering. This point is reached nearly at baked clay or brick.

experiments, made at the Mass. Institute of Technology in 1871, showed the condensation of steam in a pipe covered by one of them, as compared with a naked pipe, and one clothed with hair felt, was 100 for the naked pipe, 67 for the "cement" covering, and 27 for the hair felt.

Table of Relative Value of Non-Conductors.

(FROM CHAS. E. EMERY, PH. D.)

| Non-Conductor. | Value. | Non-Conductor. | Value. |
|---|---|---|---|
| Wood Felt......... | 1.000 | Loam, dry and open | .550 |
| Mineral Wool No. 2 | .832 | Slacked Lime... .. | .480 |
| Do. with tar...... | .715 | Gas House Carbon. | .470 |
| Sawdust.......... | .680 | Asbestos....... .... | .363 |
| Mineral Wood No. 1 | .676 | Coal Ashes......... | .345 |
| Charcoal. ......... | .632 | Coke in lumps..... | .277 |
| Pine Wood, across fibre... ......... | .553 | Air space undivided. ...... | .136 |

"Mineral wool," a fibrous material made from blast furnace slag, is a good protection, and is incombustible.

TABLE OF LOSS OF HEAT FROM STEAM PIPES.

| Thickness of Covering in inches. | Outside Diameter of Pipe, without Felt. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 in. diameter. | | | 4 in. diameter. | | | 6 in. diameter. | | | 8 in. diameter. | | | 12 in. diameter. | | |
| | Loss in units per foot run per hour. | Ratio of Loss. | Feet in length per H. P. lost. | Loss in units per foot run per hour. | Ratio of Loss. | Feet in length per H. P. lost. | Loss in units per foot run per hour. | Ratio of Loss. | Feet in length per H. P. lost. | Loss in units per foot run per hour. | Ratio of Loss. | Feet in length per H, P. lost. | Loss in units per foot run per hour. | Ratio of Loss. | Feet in length per H. P. lost. |
| 0 | 219.0 | 1.00 | 132 | 390.8 | 1.00 | 75 | 624.1 | 1.000 | 46 | 729.8 | 1.000 | 40 | 1077.4 | 1.000 | 26 |
| 1/4 | 100.7 | .46 | 288 | 180.9 | .46 | 160 | | | | | | | | | |
| 1/2 | 65.7 | .30 | 441 | 117.2 | .30 | 247 | 187.2 | .300 | 154 | 219.6 | .301 | 132 | 301.7 | .280 | 92 |
| 1 | 43.8 | .20 | 662 | 73.9 | .18 | 392 | 111.0 | .178 | 261 | 128.3 | .176 | 225 | 185.3 | .172 | 157 |
| 2 | 28.4 | .13 | 1020 | 44.7 | .11 | 648 | 66.2 | .106 | 438 | 75.2 | .103 | 385 | 98.0 | .091 | 294 |
| 4 | 19.8 | .09 | 1464 | 28.1 | .07 | 1031 | 41.2 | .066 | 703 | 46.0 | .063 | 630 | 60.3 | .056 | 486 |
| 6 | | | | 23.4 | .06 | 1238 | 33.7 | .054 | 860 | 34.3 | .047 | 845 | 45.2 | .042 | 642 |

A smooth or polished surface is of itself a good protection, polished tin or Russia iron having a ratio, for radiation, of 53 to 100 for cast iron. Mere color makes but little difference.

Table of Conducting Power of Various Substances.

(FROM PÉCLET.)

| Substance. | Conducting Power. | Substance. | Conduct'g Power. |
|---|---|---|---|
| Blotting Paper... | .274 | Wood, across fibre | .83 |
| Eiderdown....... | .314 | Cork... ......... | 1.15 |
| Cotton or Wool any density.. | .323 | Coke, pulverized. | 1.29 |
| | | India Rubber.... | 1.37 |
| Hemp, Canvas... | .418 | Wood, with fibre. | 1.40 |
| Mahogany Dust.. | .523 | Plaster of Paris.. | 3.86 |
| Wood Ashes..... | .531 | Baked Clay...... | 4.83 |
| Straw....... ... | .563 | Glass............ | 6.6 |
| Charcoal Powder. | .636 | Stone........ .... | 13.68 |

Hair or wool felt has the disadvantage of becoming soon charred from the heat of steam at high pressure, and sometimes of taking fire therefrom. This has led to a variety of "cements" for covering pipes—composed generally of clay mixed with different substances, as asbestos, paper fibre, charcoal, etc. A series of careful

Cork chips cemented together with water-glass make one of the best coverings known.

A cheap jacketing for steam pipes, but a very efficient one, may be applied as follows: First, wrap the pipe in asbestos paper—though this may be dispensed with; then lay slips of wood lengthways, from 6 to 12 according to size of pipe—binding them in position with wire or cord; and around the framework thus constructed wrap roofing paper, fastening it by paste or twine. For flanged pipe, space may be left for access to the bolts, which space should be filled with felt. If exposed to weather, use tarred paper—or paint the exterior. A French plan is to cover the surface with a rough flour paste mixed with sawdust until it forms a moderately stiff dough. Apply with a trowel in layers of about 1/4 inch thick—give 4 or 5 layers in all. If iron surfaces are well cleaned from grease, the adhesion is perfect. For copper, first apply a hot solution of clay in water. A coating of tar renders the composition impervious to the weather.

### *CARE OF BOILERS.*

The following rules are compiled from those issued by various Boiler Insurance Companies in this country and Europe, supplemented by our own experience. They are applicable to *all boilers,* except as otherwise noted.

ATTENTION NECESSARY TO SECURE SAFETY.

[Though the Babcock & Wilcox boilers are not liable to destructive explosion, the same care should be exercised to avoid possible damage to boiler, and expensive delays.]

1. **Safety Valves.**—Great care should be exercised to see that these valves are ample in size and in working order. *Overloading* or *neglect* frequently lead to the most disastrous results. Safety valves should be tried at least once every day to see that they will act freely.

2. **Pressure Gauge.**—The steam gauge should stand at zero when the pressure is off, and it should show same pressure as the safety valve when that is blowing off. If not, then one is wrong, and the gauge should be tested by one known to be correct.

3. **Water Level.**—The first duty of an engineer before starting, or at the beginning of his watch, is to see that the water is at the proper height. Do not rely on glass gauges, floats or water alarms, but try the gauge cocks. If they do not agree with water gauge, learn the cause and correct it. Water level in Babcock & Wilcox boilers should be at centre of drum, which is usually at middle gauge. It should not be carried above

4. **Gauge Cocks and Water Gauges** must be kept clean. Water gauge should be blown out frequently, and the glasses and passages to gauge kept clean. The Manchester, Eng., Boiler Association attribute more accidents to inattention to water gauges, than to all other causes put together.

5. **Feed Pump or Injector.**—These should be kept in perfect order, and be of ample size. No make of pump can be expected to be continuously reliable without regular and careful attention. It is always safe to have two means of feeding a boiler. Check valves, and self-acting feed valves should be frequently examined and cleaned. Satisfy yourself frequently that the valve is acting when the feed pump is at work.

6. **Low Water.**—In case of low water, immediately cover the fire with ashes (wet if possible) or any earth that may be at hand. If nothing else is handy use fresh coal. Draw fire as soon as it can be done without increasing the heat. Neither turn on the feed, start or stop engine, or lift safety valve until fires are out, and the boiler cooled down.

7. **Blisters and Cracks.**—These are liable to occur in the best plate iron. When the first indication appears there must be no delay in having it carefully examined and properly cared for.

8. **Fusible Plugs,** when used, must be examined when the boiler is cleaned, and carefully scraped clean on both the water and fire sides, or they are liable not to act.

ATTENTION NECESSARY TO SECURE ECONOMY.

9. **Firing.**—Fire evenly and regularly, a little at a time. Moderately thick fires are most economical, but thin firing must be used where the draught is poor. Take care to keep grates evenly covered, and allow no air-holes in the fire. Do not "clean" fires oftener than necessary. With bituminous coal, a "coking fire," *i. e.* firing in front and shoving back when coked, gives best results, if properly managed.

10. **Cleaning.**—All heating surfaces must be kept clean outside and in, or there will be a serious waste of fuel. The frequency of cleaning will depend on the nature of fuel and water. As a rule, never allow over $\frac{1}{16}$ inch scale or soot to collect on surfaces between cleanings. Handholes should be frequently removed and surfaces examined, particularly in case of a new boiler, until proper intervals have been established by experience.

The Babcock & Wilcox boiler is provided with extra facilities for cleaning, and with a little care can be kept up to its maximum efficiency, where tubulars or locomotive boilers would be quickly destroyed. For inspection, remove the handholes at both ends of the tubes, and by holding a lamp at one end and looking in at the other, the condition of the surface can be fully seen. Push the scraper through the tube to remove sediment, or if the scale is hard use the chipping scraper made for that purpose. Water through a hose will facilitate the operation. In replacing hand-hole caps, clean the surfaces without scratching or bruising, smear with oil, and screw up tight. Examine mud-drum and remove the sediment therefrom.

The *exterior* of tubes can be kept clean by the use of blowing pipe and hose through openings provided for that purpose. In using smoky fuel, it is best to occasionally brush the surfaces when steam is off.

11. **Hot Feed Water.**—Cold water should never be fed into any boiler when it can be avoided, but when necessary it should be caused to

mix with the heated water before coming in contact with any portion of the boiler.

**12. Foaming.**—When foaming occurs in a boiler, checking the outflow of steam will usually stop it. If caused by dirty water, blowing down and pumping up will generally cure it. In cases of violent foaming, check the draft and fires.

Babcock & Wilcox boilers never foam with good water, unless the water is carried too high. If found to prime, lower the water-line. It should not be carried above centre line of drum.

**13. Air Leaks.**— Be sure that all openings for admission of air to boiler or flues, except through the fire, are carefully stopped. This is frequently an unsuspected cause of serious waste.

**14. Blowing Off.**—If feed-water is muddy or salt, blow off a portion frequently, according to condition of water. Empty the boiler every week or two, and fill up afresh. When surface blow-cocks are used, they should be often opened for a few minutes at a time. Make sure no water is escaping from the blow-off cock when it is supposed to be closed. Blow-off cocks and check-valves should be examined every time the boiler is cleaned.

*Attention Necessary to Secure Durability.*

**15. Leaks.**—When leaks are discovered, they should be repaired as soon as possible.

**16. Blowing Off.**—Never empty the boiler while the brick-work is hot.

**17. Filling Up.**—Never pump cold water into a hot boiler. Many times leaks, and in shell boilers, serious weaknesses, and sometimes explosions are the result of such an action.

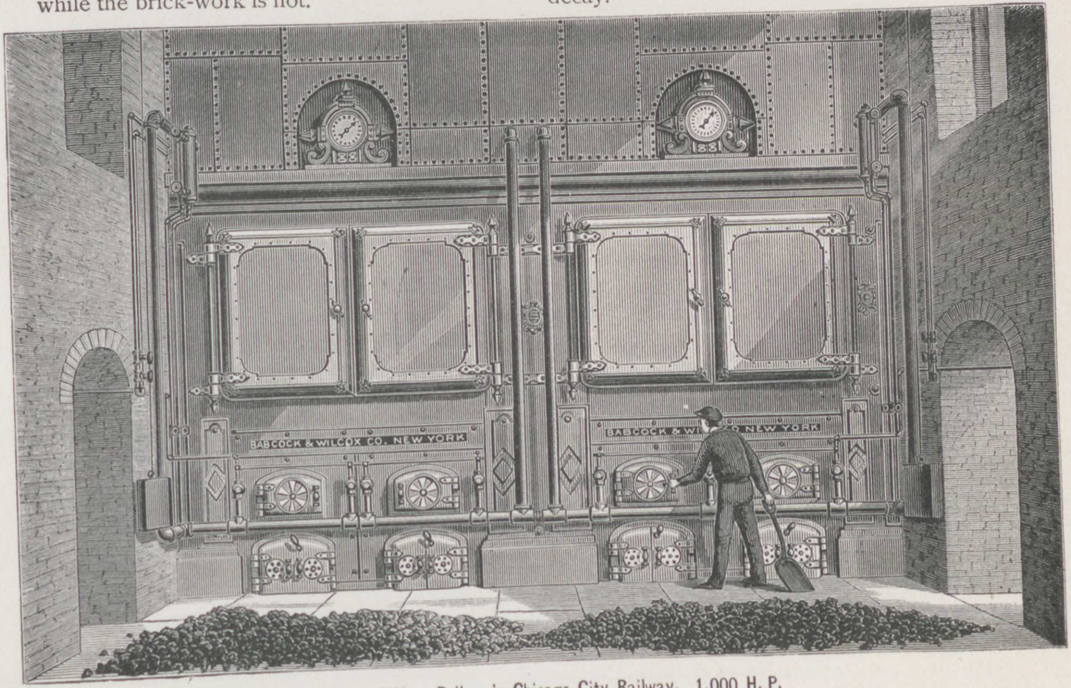
**18. Dampness.**—Take care that no water comes in contact with the exterior of the boiler from any cause, as it tends to corrode and weaken the boiler. Beware of all dampness in seatings or coverings.

**19. Galvanic Action.**—Examine frequently parts in contact with copper or brass, where water is present, for signs of corrosion. If water is salt or acid, some metallic zinc placed in the boiler will usually prevent corrosion, but it will need attention and renewal from time to time.

**20. Rapid Firing.**—In boilers with thick plates or seams exposed to the fire, steam should be raised slowly, and rapid or intense firing avoided. With thin water tubes, however, and adequate water circulation, no damage can come from that cause.

**21. Standing Unused.**—If a boiler is not required for some time, empty and dry it thoroughly. If this is impracticable, fill it quite full of water, and put in a quantity of common washing soda. External parts exposed to dampness should receive a coating of linseed oil.

**22. General Cleanliness.**—All things about the boiler room should be kept clean and in good order. Negligence tends to waste and decay.




Babcock & Wilcox Boilers in Chicago City Railway. 1,000 H. P.

## *TESTING STEAM BOILERS.**

The object of testing a steam boiler is to determine the quantity and quality of steam it will supply continuously and regularly, under specified conditions; the amount of fuel required to produce that amount of steam, and sometimes sundry other facts and values. In order to ascertain these things by observation it is necessary to exercise great care and skill, and employ the most perfect apparatus, or errors will creep in sufficient to vitiate the test and render it of no value, if not actually misleading. This is most apparent in testing the quality of the steam by a "barrel calorimeter," as at the Centennial Exposition, where an error of ¼ lb. in either of two weighings of a mass of some 400 lbs. made a difference of 3 per cent. in the final result.

5. Pressures of the steam, of barometer, and of draft in chimney.

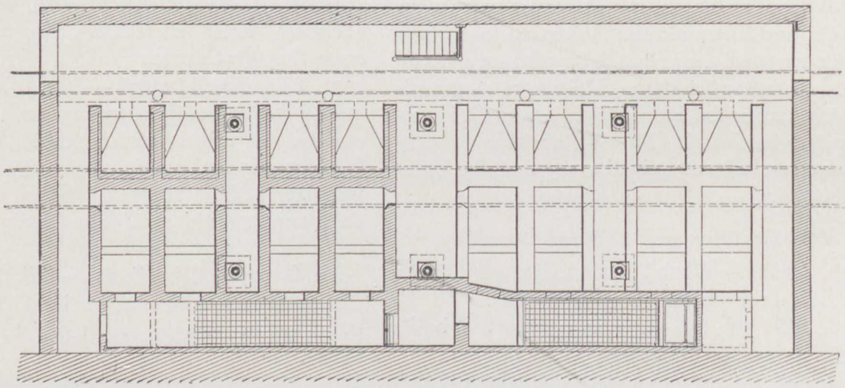
6. Weights of feed-water, of fuel, and of ashes. Water meters are not reliable as an accurate measure of feed water.

7. Time of starting and of stopping test, taking care that the observed conditions are the same at each as far as possible.

8. The quality of the steam, whether "wet," "dry," or "superheated."

From these data all the results can be figured, giving the economy and capacity of the boiler, and the sufficiency or insufficiency of the conditions, for obtaining the best results.

The amount of water evaporated per pound of coal is universally conceded to be the proper measure of the efficiency of a boiler, but in order to compare one boiler with another, each should have equally good coal, be fed with water at the same temperature and furnish steam at the same pressure. As this is impractical in making tests, a standard has been accepted to which all tests should be brought for comparison. This is called the "equivalent evaporation from and at 212°" per pound of combustible; that is, what the evaporation would have been if the coal had been without ash, the feed-water at boiling point and the steam delivered at atmospheric pressure.



Boiler House of Pencoyd Iron Works, Pencoyd, Pa. 1248 H. P.

The principal points to be ascertained and noted in a boiler test are:

1. The type and dimensions of the boiler, including the area of heating surface, steam and water space, area of water surface, and draft area through or between tubes or flues.

2. The kind and size of furnace; area of grate with proportion of air spaces therein, height and size of chimney, length and area of flues.

3. Kind and quality of fuel and amount of ash and water therein. The latter is a more important item than is generally understood, as it not only adds to the weight without adding to the value of the fuel, but the heat taken to evaporate, and send the steam up chimney in a highly superheated condition, adds to the unobserved waste.

4. Temperatures, of external air, of fire-room, of chimney gases, of fuel, water and of steam.

It may be determined by the following formulæ:

Let W = the observed evaporation per lb. of combustible.
" $t$ = the observed temperature of feed.
" T = the temperature of steam at observed pressure.
" H = the total heat of steam at the observed pressure.
" W′ = equivalent evaporation from and at 212°.

$$W' = W\left(1 + \frac{0.3\,(T - 212) + (212 - t)}{966}\right)$$

or, . . . $$W' = W \times \frac{H + 32 - t}{966}$$

The value of T and H may be found by reference to "steam table" on another page, (49.)

* This subject will be found very fully treated in the report of a committee to the American Society of Mechanical Engineers, and the discussions on the same. Transactions A. S. M. E., Vol. VI, pp. 256-351.

# TESTS of the BABCOCK & WILCOX BOILERS

Engineering Office of Chas. E. Emery,
No. 7 Warren Street, New York,
March 21, 1879.

Messrs. Babcock & Wilcox,
No. 30 Cortlandt Street, New York.

Gentlemen: On the 4th and 5th of February, 1879, I made a trial of the Babcock & Wilcox Boilers and Corliss engines in the Raritan Woolen Mills, Raritan, N. J., the results of which are shown in the following report:

There were two boilers tested of the water-tube type, manufactured by you and known by your name, rated jointly at 360 horse-power, and reported to contain 4,080 square feet of heating surface, and 103 square feet of grate surface. These boilers were erected side by side and connected so that they could be used separately or conjointly in connection with or independent of a number of Lancashire drop-flue boilers, three boilers of the latter kind having been removed to make room for yours. All the boilers were connected to a single chimney through a Green's economizer in the flue. A large portion of the steam generated appeared to be used in the dye house and for heating purposes. A portion of the boilers were employed, however, to supply steam to two pairs of engines, of equal size, operating the mill, one pair being of the Wright patent, put in many years since, and the other of Corliss make, erected within a year. Each steam cylinder was 20 inches in diameter with 48 inches stroke of piston. The engines are provided with Bulkley condensers. In the ordinary working of the mill your boilers were used to supply steam to both pairs of engines.

Your contract contained a guarantee that the boilers should furnish sufficient steam to develop the rated power (360 H. P.) in a Corliss engine, and that the evaporation should equal at least 9 pounds of water from a temperature of 180° per pound of coal containing not more than 12 per cent. of refuse. In a preliminary trial, part of the load on the Wright engines was transferred to the Corliss engines; but it was soon found that the latter did not require all the steam your boilers would generate economically; so two trials were made, one of $4\frac{1}{6}$ hours' duration, using your boilers with reduced draft to supply steam to the Corliss engines only, and taking data to ascertain the economy of the engines; the other of fully 12 hours' duration, using the boilers at *maximum power* on a dull day without forcing the fires, part of the steam being used to operate the Corliss engines, the remainder blown into the pipe system of the other boilers, which were working at a much less pressure.

### *Trial of the Boilers.*

The experiment commenced at 6.01 A. M., and closed at 6.38 P. M. In starting, steam was raised by spreading the banked fires left from the previous day. When the pressure reached 80 pounds the fires were hauled, all refuse removed, and fires started anew with wood, which in calculation has been considered equal in calorific value to $\frac{4}{10}$ its weight of coal. The fires were maintained with coal during the day, finally hauled, allowed to cool, the combustible portion deducted from the coal charged, and the refuse weighed separately. The experiment was closed when the boilers stopped making steam at 80 lbs. pressure, with water in the glass gauges at same height as in starting.

During the trial, all the coal consumed was weighed in an iron wheel-barrow, balanced when empty by a fixed weight, and each barrow load was adjusted at the scale to weigh 200 pounds net. All the water evaporated was measured in a tank provided with a heavy float connected through a fine chain to an index showing a water level on an exterior scale, divided decimally. By weighing water out of the tank, its capacity was found to be 5,172 pounds of water between the limits employed.

A complete record was kept of the coal, water, steam pressure and various temperatures, and the quality of the steam was tested with a calorimeter at frequent intervals. The proprietors of the mill took the proper business precaution of stationing observers at each point, who kept entirely independent records, agreeing with those taken by my assistants. The coal used was clean nut coal from the Lackawanna region. It had been exposed to the weather during the winter, and when first taken from the pile was wet, but a sufficient quantity for the trial was brought under shelter a few days in advance, so that the coal actually used was bright and appeared dry. The results of the trial are as follows:

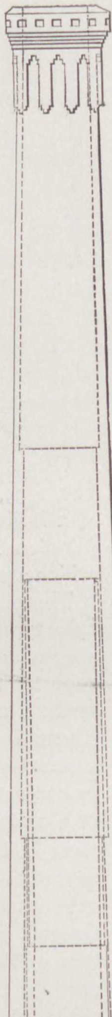
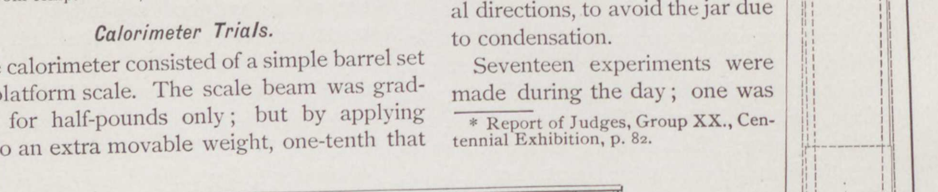
| | |
|---|---|
| Average steam pressure, . . . . . . . | 71.63 |
| Average temperature, | |
| " " of fire room, . . . . . | 44.00 |
| " " of water in feed tank, . . | 90.47 |
| " " of water entering boiler after passing through a heater in flue, | 110.59 |
| " " of up-take boiler No. 1 by pyrometer (evidently wrong), . | 381.87 |
| " " of flue beyond feed water heater | 453.23 |
| Wood used in starting fires, 730 lbs., equivalent of coal (730 x .4) . . . . . . . . lbs. | 292 |
| Coal put in furnaces during experiment, . . " | 19,827 |
| Total of above. . . . . . . " | 20,119 |
| Combustible in refuse at close of experiment, . " | 820 |
| Total coal consumed, including equivalent of wood, . . . . . . . . lbs. | 19,299 |
| Refuse from coal removed during experiment, . " | 749 |
| Refuse from coal at close of experiment, . . " | 2,134 |
| Total, . . . . . . . . " | 2,883 |
| Actual per centage of refuse, (2,883 ÷ 19,299 x 100 = ) . . . . . . . | 14.94 |
| Combustible consumed, (19,299 — 2,883 = ) . lbs. | 16,416 |
| Coal with 12 per cent. refuse agreed upon, equivalent to that actually consumed, [16,416 ÷ (100 — 12) = ] . . . . lbs., | 18,654.5 |
| Total weight of water actually evaporated at pressure of 71.63 lbs. from temperature 110.59°, . . . . . . lbs., | 161,573.28 |
| Equivalent evaporation at pressure of 70 lbs. from temperature of 180°, as agreed upon, | 172,592.58 |
| Evaporation per lb. of coal, with 12 per cent. of refuse, at pressure of 70 lbs. from temperature of 180° . . . . . . . | **9.252** |
| Evaporation per lb. of combustible, atmos. press. from temp. of 212°, . . . . . . | **11.221** |

### *Calorimeter Trials.*

The calorimeter consisted of a simple barrel set on a platform scale. The scale beam was graduated for half-pounds only; but by applying thereto an extra movable weight, one-tenth that of the other, carefully leveling the platform, and in weighing bringing the end of the beam just clear of the guard, it was possible to read to one-tenth, or even .05 of a pound. In an inclined position, through the side of the barrel, was fixed a thermometer graduated to 1/4 degrees, and readily read to 1/8 degrees. A small iron propeller on a vertical shaft was arranged in the barrel. In operations, the barrel was nearly filled with cold water, which was heated with steam, when the increase in weight showed the weight of steam taken from the boiler, and the increase in temperature measured the quantity of heat in the steam. The steam was taken from the boiler near the issuing current, through a 2-inch pipe reduced outside of the boiler to 3/4 of an inch, and again near the outer end by an inserted nipple to 5/16 of an inch, substantially on the plan recommended in a previous article on the subject.* To the end of the steam-pipe a short piece of hose was connected through a valve; the pipe was carefully felted, and was heated previous to each experiment by wasting steam through it before putting the hose into the calorimeter. The end of the hose was perforated in several directions, to avoid the jar due to condensation.

Seventeen experiments were made during the day; one was

* Report of Judges, Group XX., Centennial Exhibition, p. 82.

Boiler-House and Chimney for Babcock & Wilcox Boilers, at Somersett Manufacturing Co.'s Woolen Mills, Raritan, N. J. 1,080 H. P.

rejected, in which the thermometer scale was seen to move by bringing the hose too near the instrument. The results were calculated from the records of the remaining sixteen experiments, on the following basis :

Let W = original weight of water in calorimeter.
Let $w$ = weight of water added by heating with steam.
Let T = total heat in water due to the temperature of steam at observed pressure.
Let H = total heat of steam at observed pressure.
Let $l$ = latent heat of steam at observed pressure.
Let $t$ = total heat of water corresponding to temperature of water in calorimeter.
Let $t'$ = total heat in water corresponding to final temperature of water in calorimeter.
Let E = heating efficiency of the steam furnished, compared with saturated steam between the same limits of temperature.
Let Q = quality of steam explained hereafter.

$$\text{Then } E = \frac{W\ (t' - t)}{w\ (H - t')} \ldots\ldots\ (1)$$

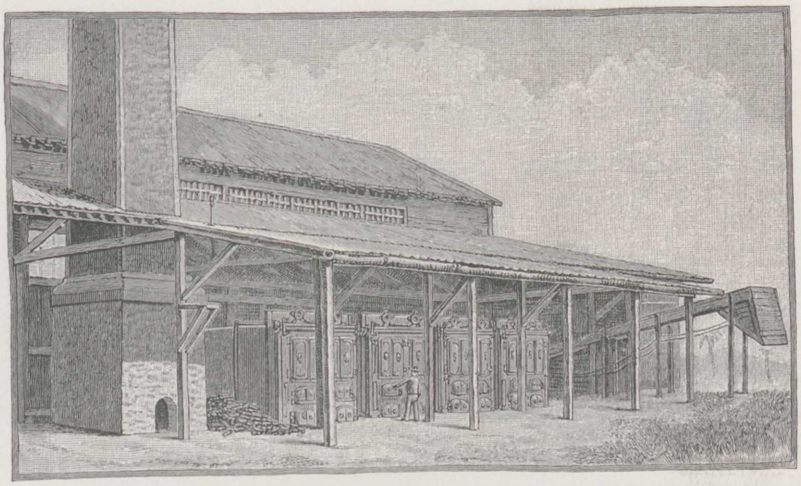
When $Q > 1$, the number of degrees steam is superheated $= 2.0833\ l\ (Q - 1)$.

In the present case $Q = .98955$. Per centage of moisture in steam = 1.045.

This is *practically dry steam,* and equal in quality to that furnished by boilers of any type not provided with superheating surface. The experiments show, in a gratifying manner, that you have succeeded in overcoming a great difficulty often experienced with boilers constructed of a combination of small chambers to reduce the danger of explosion. The deficiency of ordinary boilers in furnishing dry steam is little known, though the economy is materially affected.

### *Engine Trials.*

The preliminary trial of engines gave the following results :



Babcock & Wilcox Boilers at Yngenio, Central Ysabel, Manzanillo, Cuba. 1,000 H. P

The value of E was ascertained by the formula separately for each experiment. The average value was .9916, showing that the steam lacked but $\frac{84}{100}$ of 1 per cent. of the quantity of heat required for producing perfectly dry or saturated steam between the same limits of temperature.

The value of Q may be found directly from the following equation :

$$Q = \frac{1}{l}\left(\frac{W}{w}(t' - t)\ (T - t')\right) \ldots\ldots (2)$$

or, from the average of the heating efficiencies, by the following :

$$Q = 1 - \frac{(H - t')\ (1 - E)}{l} \ldots\ldots\ (3)$$

Then when $Q < 1$, the per centage of moisture in steam $= 100\ (1 - Q)$.

| | | |
|---|---|---|
| Duration of experiment, . . . . | 4.1 | hours. |
| Average steam pressure in boilers, . . | 93.94 | pounds. |
| Average vacuum in condenser, . . . | 21.5 | inches. |
| Average revolution of engine per minute . | 64.492 | |
| Water evaporated per hour, . . | 8830.244 | pounds. |
| Average initial pressure in steam cylinders, | 84.425 | " |
| Mean effective pressure in cylinders, . | 30.1275 | " |
| Average point of cut-off, . . . . | .129 | stroke. |
| Average indicated H. P. (both engines), . | 292.613 | |
| Maximum H. P. shown by a complete set of diagrams, . . . . . | 315.580 | |
| Water per indicated horse-power per hour, | 30.177 | pounds. |

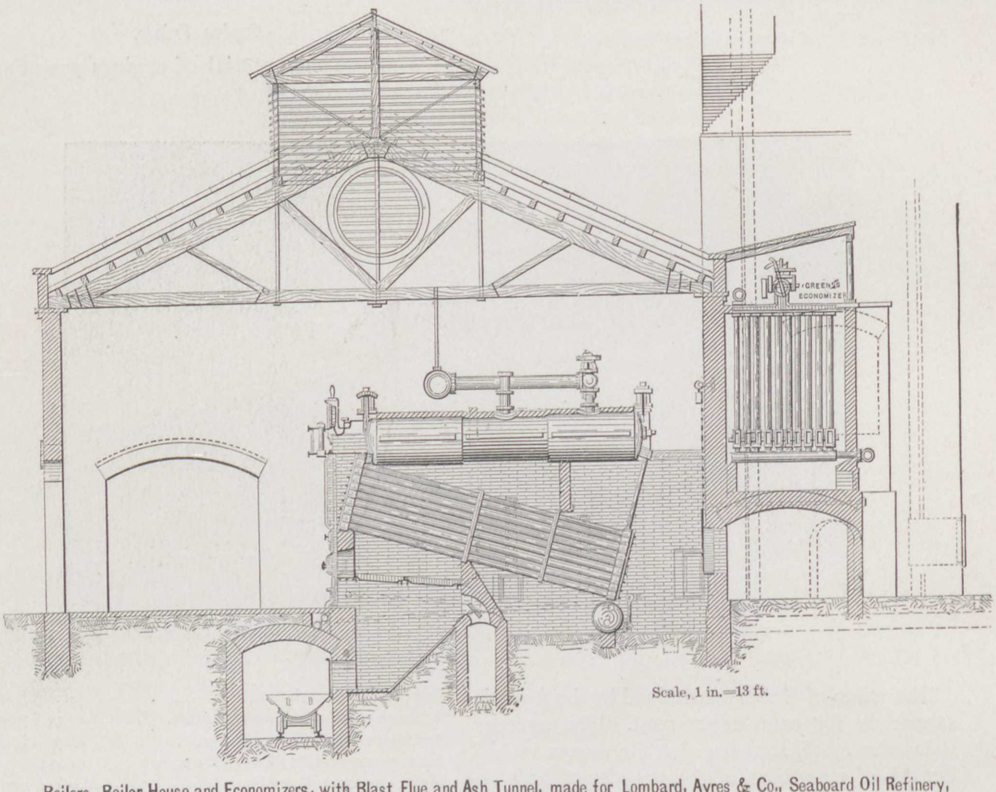
The steam pipe was 131 feet long and other conditions were unfavorable for the economical development of power in the engines. It is, in fact, popularly supposed that this class of engines develops a horse-power for ⅔ the quantity of steam required in this case.

The duration of the boiler experiment was 12 hours and 37 minutes, of which fully 13 minutes were necessarily lost in starting and hauling fires. On this basis the water was evaporated in 12.4 hours, or at the equivalent rate of 13,919 pounds per hour for feed water at 180 degrees. On the basis that any good engine under fair conditions will require but 30 pounds of water per horse-power per hour, your boilers, during this experiment, though not forced to their utmost, developed under condition agreed upon, 13919 ÷ 30 = 464 horse-power, *or 104 horse-power in excess of the guaranteed power*.

The coal required per horse-power per hour is evidently dependent in any case upon the economy of the boiler and engine jointly. With an evaporation of 9.252 pounds of water per pound of coal, and 30 pounds of water per horse-power in the engine, there would be required per horse-power per hour 3.24 pounds of coal. This boiler performance, however, is rarely obtained in ordinary practice, so generally a low cost of power in fuel is due to using an excellent engine with a fair boiler. For instance, during the official trial of one of the most prominent pumping engines in this country, the boilers, which were specially designed to secure economy, actually evaporated but 8.31 pounds of water at a pressure of 89.4 pounds from a temperature 100° per lb. of *Cumberland* coal; yet the engine was so economical that there was required but 1.69 lbs. of coal per horse-power per hour. The equivalent evaporation of your boilers from the same temperature with *anthracite nut* coal, much inferior to Cumberland, on the basis of the trial above mentioned, is 8.547 pounds of water per pound of coal; so if your boilers were used in connection with that particular pumping engine, there would be required but 1.64 pounds of the inferior coal per horse-power per hour.

The economical performance of your boilers could undoubtedly be rendered still greater by reducing the rate of evaporation. The more fuel burned per square foot of heating surface in a given time the greater the quantity of heat lost in the chimney, so that, within certain limits, using proper proportion, the economy increases as the rate of evaporation is diminished, though in a much less ratio. To accomplish this result to the fullest extent, however, the boiler would probably need to be so proportioned that it would not develop a maximum of 464 horse-power, or upward, as in its present form.

Very truly, yours, CHAS. E. EMERY.

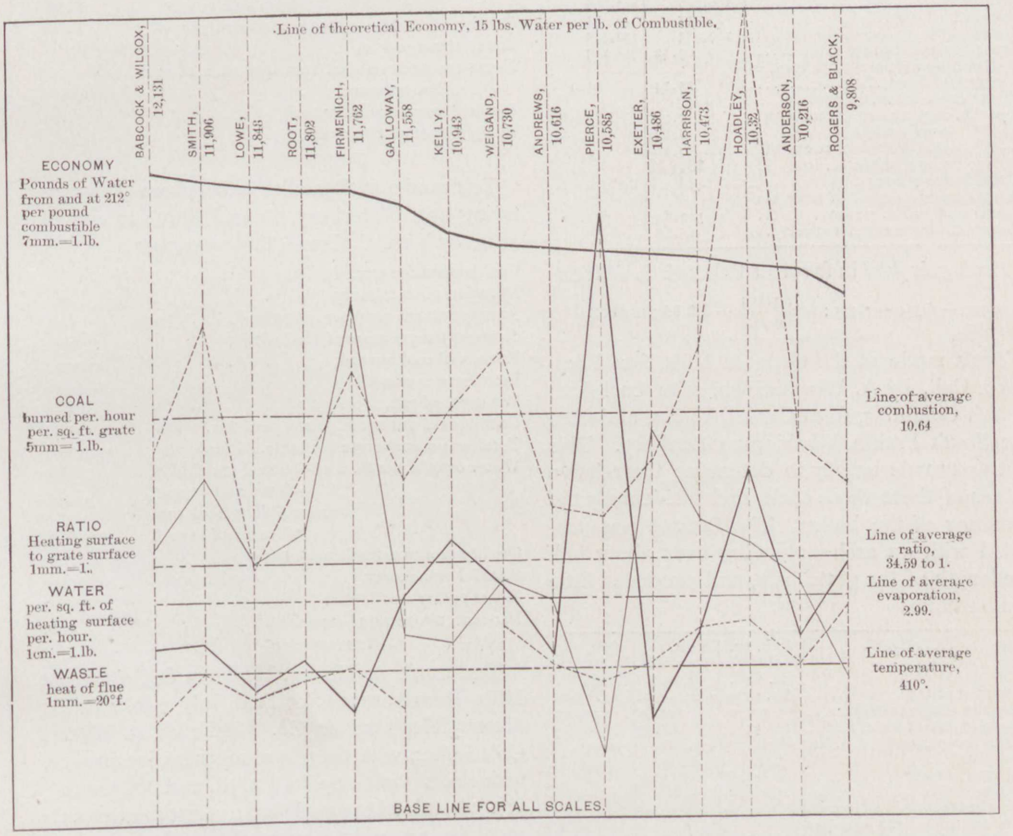



Boilers, Boiler House and Economizers, with Blast Flue and Ash Tunnel, made for Lombard, Ayres & Co., Seaboard Oil Refinery, Bayonne, N. J., 15 orders, 2,246 H. P.

## *CENTENNIAL BOILER TESTS.*

At the U. S. Centennial Exposition held in Philadelphia in 1876, a careful test was made of the different boilers there exhibited, except the Corliss, which was not placed in competition. The results of these tests have been condensed in the following diagram, which gives graphically not only the relative evaporation, but the rate of combustion of coal per square foot of grate, the ratio of heating to grate surface, the water evaporated per square foot of heating surface, and the waste heat in the flue. The height of the diagram is 105 millimeters, and represents the to difference in the construction of the boilers, by which the heating surface was rendered more effective. The fact that the best economic results were obtained by a boiler under average conditions in other respects, is significant.

In their report, the Judges said: "The awards of the Judges were not based upon the trials; in fact, the latter were not commenced until the awards had been made by another committee of the same group. This report has been confined to a statement of what actually took place during the trials, without expressing opinions on the all-important question of value, but more particu-




*theoretic value* of the combustible used in the experiments. In the line of "economy" the boilers are arranged in the order of their relative economy, as shown in the table. The distance of this line from the base, relative to the whole height, gives the *percentage of useful effect* in each case. All the lines have scales measured in millimeters, from a common base.

By reference to the lines of averages, it will be seen that boilers at the extremes of economy, had an average of each of the conditions. The different results are, therefore, to be attributed larly the trustworthiness of the different mechanical details and arrangements employed by the various exhibitors. Many of these questions can only be settled by long practical use, under different circumstances as to management and the kind of fuel and water used."

In view of that statement it is an interesting fact, that of all the *fifteen* boilers tested at the Centennial, *only three* can be said to be now fairly in the market, and of these, the Babcock & Wilcox, which showed the best results there, is the only one extensively sold in this country.

*Comparative Test,*

made at the Oliver Wire Works, Pittsburgh, Pa., March, 1883, by Wm. Kent, M. E., between two Babcock & Wilcox boilers of 416 H. P., and eight "two flue" boilers—six of them being 28 ft. long, 42 inches diameter, 14-inch flues, and two of them 26½ feet long, 40 inches diameter, 14-inch flues. Total grate-surface, 165 ft.

| | B. & W. | Ret. Flue. |
|---|---|---|
| Date of test | Mch. 12 to 17 | Mch. 19 to 21 |
| Coal, bituminous, lump and nut. | | |
| Duration of test, hours | 114 | 40.75 |
| Average steam pressure | 95 | 95 |
| Average temperature of feed, deg. | 37 | 180 |
| Water evaporated ... lbs. | 1,512,763.2 | 880,776 |
| Coal fired ... " | 190,228 | 147,668 |
| Per cent. of ash | 11 | 11 |
| Combustible | 169,303 | 131,425 |
| Grate-surface, square feet | 69.12 | 165 |
| Coal consumed per square foot, of grate per hour | 24.14 | 21.9 |
| Water evaporated, in pounds | | |
| per lb. coal under actual con. | 7.952 | 5.964 |
| " combustible " " | 8.826 | 6.70 |
| " coal from and at 212° | 9.709 | 6.334 |
| " combustible ... do | **10.909** | **7.115** |
| Rated horse-power | 416 | not given. |
| Horse-power developed from 212° feed and 70 lbs. steam | 522.84 | 741.36 |
| Per cent. above rated capacity | 25.68 | |

*Saving in fuel* in favor of Babcock & Wilcox:

$9.709 - 6.334 = 3.375$; and $\frac{3.375}{9.709} =$ **34.76** per cent.

Tests made at the Genesee Mills, San Francisco, Cal., by A. Worthington, with coal from British Columbia, from Cardiff, Wales, and from the South Prairie, Washington Territory. This test was made largely to determine the relative values of these three coals, and incidentally the economy of the boiler. The furnace was provided with an arch extending over about half the length of the grate bars, and produced little or no smoke:

| Date ... 1883. | Feb. 20. | Feb. 27. | Feb. 28. |
|---|---|---|---|
| Coal | Welling'n Br. Col. | Cardiff, Wales | So. Prairie Wash. T. |
| Duration of test | 6 hr. 17 m. | 7 hr. 23 m. | 6 hr. 35 m. |
| Average steam pressure | 119.2 | 117.68 | 117.87 |
| Average temp'ture of feed | 59 | 61.87 | 61.97 |
| Water evaporated ... lbs. | 28,329 | 32,376 | 30,345 |
| Coal fired ... " | 3,777 | 4,032 | 4,059 |
| Per cent. of ash | 13.78 | 19.07 | 13.94 |
| Combustible ... lbs. | 3,156.5 | 3,263 | 3,493 |
| Grate-surface ... sq. ft. | 21.25 | 21.25 | 21.25 |
| Coal consumed per hour per sq. ft. grate, lbs | 28.2 | 25.6 | 28.9 |
| Water evaporated, (in lbs.) | | | |
| per lb. coal—actual con. | 7.5 | 8.02 | 7.47 |
| " " —from and at 212° | 8.97 | 9.95 | 8.76 |
| " combust. act. con. | 9.3 | 9.54 | 8.88 |
| " " from and at 212° | **11.12** | **11.84** | **10.42** |
| Rated horse-power | 136 | 136 | 136 |
| Horse-power developed | 186 1 | 173.5 | 182.3 |
| Per ct. above rated capacity | 36.8 | 27.5 | 34 |

Test made at Harrison, Havemeyer & Co. (now Harrison, Frazier & Co.), Franklin Sugar Refinery, Philadelphia, Pa., by C. A. Brinley, Chief Engineer, being the result of four separate runs of 72 hours each, in October, 1883, and April and May, 1884, on regular work, with "Buckwheat" anthracite coal from different mines, after boilers had been in constant use for five years:

| | |
|---|---|
| Duration of test, in hours, | 288 |
| Average steam pressure, in pounds, | 73.52 |
| Average temperature of feed water in tank, | 82.195 |
| Pounds of coal burned, | 216,987.8 |
| Pounds of combustible, | 179,295.3 |
| Per cent. of ash, | 17.41 |
| Coal burned per square foot grate, per hour, | 14.685 |
| Total water evaporated at temp. of feed, lbs. | 1,765,926 |
| Water evaporated, in pounds, | |
| per lb. coal—actual conditions, | 8.124 |
| " " —from and at 212° | 9.49 |
| " combustible, actual conditions, | 9.833 |
| " " from and at 212° | **11.485** |
| Quality of steam—13 tests, moisture, per ct. | 1.28 |
| Rated horse-power, | 187 |
| Horse-power developed from feed, at 212° and 70 lbs. pressure, | 231.61 |
| Per cent. above rated capacity, | 23.72 |
| Temperature of flue gases, | 455. |

Test made at Benedict & Burnham Manufacturing Co., Waterbury, Conn., March 17 and 18, 1883, by Wm. E. Crane, their engineer:

| | |
|---|---|
| Coal, anthracite egg, | |
| Duration of test, hours, | 22 |
| Average steam pressure, pounds, | 60 |
| Average temperature of feed water, | 36° |
| Pounds of coal burned, | 21,400 |
| Pounds of combustible, | 18,626 |
| Per cent. of ash, | 12.9 |
| Coal burned per sq. ft. grate, per hour, lbs. | 16.21 |
| Total water evaporated at temp. of feed, " | 175,579 |
| Water evap'd per lb. coal—actual conditions, | 8.20 |
| " " " " —from and at 212°, | 9.93 |
| " " " combustible actual con. | 9.42 |
| " " " " from and at 212°, | **11.41** |
| Quality of steam (moisture), per cent. | 1.81 |
| Rated horse-power, | 250 |
| Horse-power developed, | 312.12 |
| Per cent. above rated capacity, | 24.8 |

Test made at Messrs. Hepburn & Co's Grant Mills, Ramsbottom, Scotland, July 24th, 1884, by Messrs. Hepburn & Co. Babcock & Wilcox Co's Boiler, with the patent regenerative furnace, with dross "pick-up" @ 4/9d. and "Crosses" at 5/3d., mixed to equal parts. Cost to evaporate 1000 lbs. water into steam @ 70 lbs. pressure, 2.82 pence, sterling:

| | |
|---|---|
| Duration of test, in hours, | 8 |
| Average steam pressure, by gauge, | 50 |
| Average temperature of feed water. | 208° |
| Pounds of coal burned, | 5,824 |
| Pounds of refuse, | 630 |
| Pounds of combustible, | 5,194 |
| Per cent. of ash, | 11 |
| Coal burned per sq. foot grate, per hour, lbs. | 24.26 |
| Total of water evaporated at temp. of feed, " | 55,300 |
| Water evaporated, | |
| per lb. coal—actual conditions, lbs. | 9.497 |
| " " —from and at 212°, " | 10.627 |
| " combustible actual conditions, " | 9.826 |
| " " from and at 212°, " | **10,998** |
| Rated horse-power, | 136 |
| Horse-power developed from feed at 212° and 70 lbs. pressure, | 232.2 |
| Per cent. above rated capacity, | 70.7 |

### *Comparative Test,*

made at the station of the Brush Electric Light Co., Philadelphia, between the Babcock & Wilcox and Return Tubular boilers, by J. C. Hoadley, on the part of the Babcock & Wilcox Co., and W. Barnet Le Van, on the part of the Brush Electric Light Co., October, 1882, the conditions as to quality of coal and management of fires being much in favor of the return tubular boilers, as was certified to by both experts. This statement and full data and details of calculation were published in *Van Nostrand's Magazine*, 1883, copy of which will be furnished on application.

#### 1. Test by Evaporation of Water.

| Points Observed. | Babcock & Wilcox. | Return Tubular. |
|---|---|---|
| Date of test........ ....... | Oct. 18, 19, 20. | Oct. 23, 24, 25. |
| Duration of test........... | 21.5 hours | 16 hours. |
| Quality of coal (anthracite Chestnut)............... | Wet and dirty | Screened and dry. |
| Coal thrown on grate...... | lbs. 16,388.5 | 13,171.5 |
| Surface water in coal....... | " 1,207.8 | 378 |
| Dry coal thrown on grate.. | " 15,180.7 | 12,793.5 |
| Wood used for kindling.... | " 462 | 319 |
| Cotton waste, to start fires. | " 72.5 | 34.5 |
| Ashes and residue.......... | " 3,305 | 2,697 |
| Combustible (in coal) consumed.................... | " 11,875.7 | 10,096.5 |
| Combustible = wood x 0.36. | " 166.3 | 115 |
| Combustible = cotton waste | " 72.5 | 34.5 |
| Total combustible consumed.................. | " 12,114.5 | 10,246 |
| Heat units apparently received by boiler.......... | 134,410,015 | 106,300,397 |
| Heat units actually received — water allowed for...... | 130,176,100 | 104,110,609 |
| Heat units received per 1 lb. of combustible........... | 10,745.48 | 10,161.1 |
| Water evaporated from and at 212° F. per 1 lb. combustible... .... ......lbs. | 11.127 | 10.522 |
| Apparent efficiency, per ct. | 74.18 | 70.15 |
| Heat units required to dry the coal........... ...... | 1,497,793 | 482,555 |
| Water evaporated from and at 212° F. per 1 lb. of combustible expended in drying the coal,... . ....lbs. | 0.128 | 0.049 |
| Water actually evaporated from and at 212° F. per 1 lb. of combustible.... ... | **11.255** | **10.571** |
| Actual efficiency, per cent. of theoretical............ | **75.03** | **70.47** |

*Comparative Economy by the Evaporative Test:*

$11.255 - 10.571 = 0.684$; and $\frac{0.684}{10.57} = 0.0647 =$ **6.47** per cent.

#### 2. Test by Power Developed Through Engines.

| Points Observed. | Babcock & Wilcox. | Return Tubular. |
|---|---|---|
| Mean indicated horse-power...... | 130.41 | 137.78 |
| Duration of experiments as above.................. ..hours | 21.5 | 16 |
| Combustible consumed.. ....lbs. | 12,114.5 | 10,246 |
| Combustible consumed per hour................. ...... " | 563.46 | 640.375 |
| Combustible consumed per H. P. per hour............ " | **4.321** | **4.648** |
| Water evaporated........... " | 130,156 | 104,562 |
| Water evaporated per hour... " | 6,054 | 6,535 |
| Water evaporated per H. P. per hour................... " | 46.57 | 47.43 |
| Dry steam per H. P. per h'r.. " | 45.1 | 46.45 |
| Leakage per H, P. her hour.. " | 10.43 | 12.33 |
| Dry steam *used* per H. P. per hour......... ........ " | 34.67 | 34.12 |

*Comparative Economy by the Engine Test:*

$4.648 - 4.321 = 0.327$; and $\frac{0.327}{4.321} = 0.0757 =$ **7.57** per cent.

#### 3. Test by Waste Heat in Chimney.

| Character of Waste. | Babcock & Wilcox. Parts in 100. | Return Tubular. Parts in 100. |
|---|---|---|
| Loss of heat carried off by heated gases in chimney. | 20.54 | 25.47 |
| Loss by imperfect combustion, and radiation....... | 4.43 | 4.06 |
| Aggregate losses........... | 24.97 | 29.53 |
| Actual efficiency by evaporative test................. | 75.03 | 70.47 |
| Total heating power of combustible.............. | 100.00 | 100.00 |

Loss carried off by hot gases, Ret. Tub. boilers..25.47 pr. ct.
Loss carried off by hot gases, B. & W. boilers...20.54 pr. ct.

Difference; greater loss by Ret. Tub. boilers.... 4.93 pr. ct.

This difference, or excess of heat lost by the Return Tubular boilers, divided by the efficiency of these boilers (70.47 per cent.), gives the ratio of the excess of loss to actual efficiency:

$$\frac{4.93}{70.47} = 0.06996 = \textbf{7.00} \text{ per cent.}$$

#### 4. Test by Light.

| Points Observed. | Babcock & Wilcox. | Return Tubular. |
|---|---|---|
| 1. Indicated horse-power, mean of all tests....... | 130.41 | 137.78 |
| 2. Hours run............. | 21.5 | 16 |
| 3. No. of arc lights run.... | 121 | 128.75 |
| 4. Average H. P. per light. | 1.0703 | 1.0701 |
| 5. Pounds of combustible per light per hour..... | 4.6567 | 4.9738 |

*Comparative Economy by the Light Test:*

$4.9738 - 4.6567 = 0.3171$; and $\frac{0.3171}{4.6567} = 0.0681 =$ **6.81** per cent.

#### 4. Summary of Results by the Four Methods.

| Tests. | Babcock & Wilcox. | Return Tubular. | Difference in favor of B. & W. Boilers. | Difference *per centum.* |
|---|---|---|---|---|
| Evaporative test......... | 11.254 | 10.570 | .684 | 6.47 |
| Power, engine test....... | 4.321 | 4.648 | .327 | 7.57 |
| Light test................ | 4.6567 | 4.9738 | .3171 | 6.81 |
| Test by loss at chimney.. | 20.54 | 25.44 | 4.9 | 7.00 |
| Mean of four tests....... | ..... | .... | ..... | 6.96 |

*Explanation of Table.*—The Babcock & Wilcox boilers evaporated *more* water for each pound of combustible consumed; consumed *less* combustible per hour for each indicated H.P. produced, consumed *less* combustible per hour for each arc light in use; and lost *less* heat by hot gases escaping to the chimney, than the Return Tubular boilers.

While doing this, they were evaporating 6054 pounds of water per hour, into steam, containing only 3.15 per cent. of entrained water, leaving 5863 pounds of dry steam per hour, enough at the rate of 30 pounds of dry steam per hour for each horse-power to supply 195 horse-power, which is 30 per cent. above their rated power.

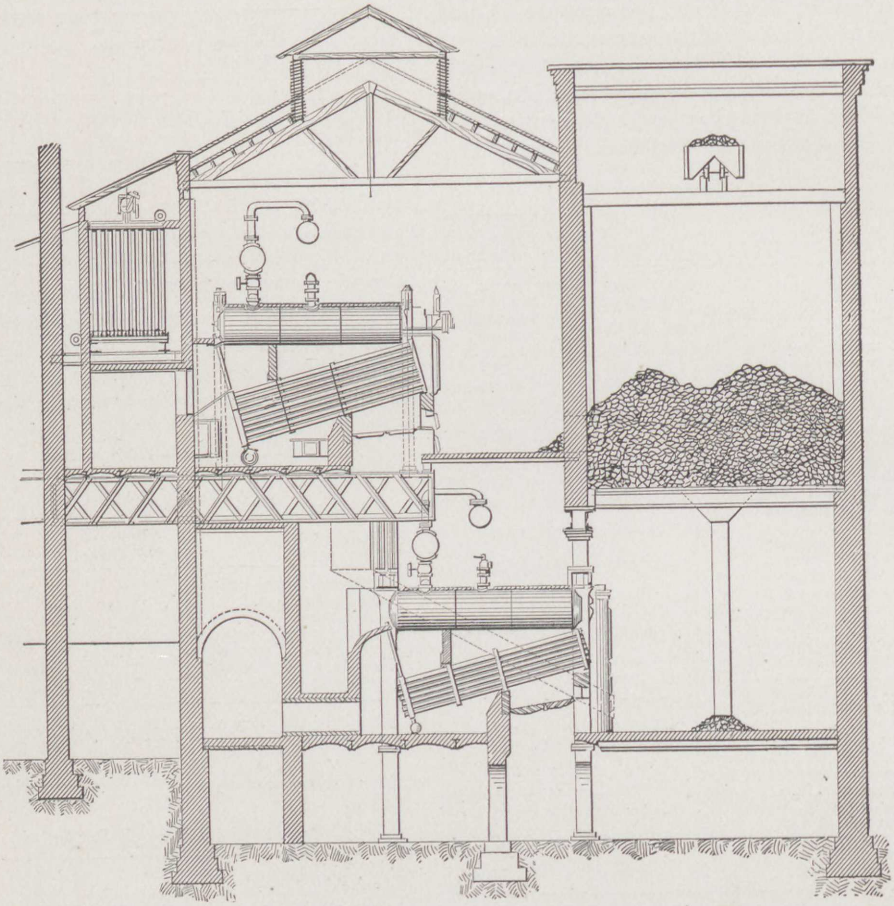
The general result is a difference of about 7 per cent. in favor of the Babcock & Wilcox boilers, arrived at by four independent methods of comparison, all free from objection, and, together, mutually confirmatory in the highest degree.

This comparison leaves out of view all disparity of coal save the ascertained difference in surface water; this, if allowed for, would greatly increase the difference.

*Other Tests*

The following tests, showing the evaporative efficiency of the Babcock & Wilcox boilers, actual and comparative, with different kinds of fuel, which have been made at various times, by different engineers, have been condensed for the purpose of a more ready comparison.

Test made at Harrison & Havemeyer's Sugar Refinery, Philadelphia, January, 1879, by their engineer and usual fireman, under general working conditions, for five days of 24 hours each:



The Brooklyn Sugar Refining Co., Brooklyn, N. Y., 5 orders, 1876 to 1888, 3952 H. P. Babcock & Wilcox Boilers.

| | | |
|---|---|---|
| Coal, anthracite, egg size, not screened. | | |
| Duration of test, hours, | | 120. |
| Average steam pressure, in pounds, | | 62.50 |
| Average temperature of feed, | | 165.8c |
| Water evaporated, | lbs. | 733,660 |
| Coal fired, | " | 79,147 |
| Per cent. of ash, | | 13.7 |
| Combustible, | lbs. | 68,297.5 |
| Grate surface, | sq. ft. | 50.75 |
| Coal consumed per sq. foot of grate per hour, | | 12.99 |
| Water evaporated, in pounds: | | |
| Per lb. coal under actual conditions, | | 9.27 |
| " combustible, " " | | 10.74 |
| " coal from and at 212°, | | 9.71 |
| " combustible " | | **11.6** |
| Rated horse-power, | | 190 |
| Horse-power developed, | | 220 |
| Per cent. above rated capacity, | | 13.63 |

Test of a Babcock & Wilcox boiler, made at the Laboratory of Thos. A. Edison, Menlo Park, N. J., Jan., 1881, by Chas. L. Clarke, M. E.

| | |
|---|---|
| Anthracite coal, egg size. | |
| Duration of test in hours, | 12 |
| Average steam pressure, | 85 |
| Average temperature of feed, | 195 |
| Water evaporated in pounds, | 28,181 |
| Coal fired, " " | 2,998 |
| Per cent. of ash, | 12.8 |
| Combustible in pounds, | 2,614 |
| Grate-surface, square feet, | 26.83 |
| Coal burned per sq. foot of grate, per hour, lbs., | 9.3 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 9.4 |
| " combustible " " " | 10.78 |
| " coal from and at 212°, " | 9.9 |
| " combustible " " | **11.36** |
| Rated horse-power, | 75 |
| Horse-power developed, | 83 |
| Per cent. above rated capacity, | 10.6 |

Test of a Babcock & Wilcox boiler, made at the Electric Lighting Station of the Edison Co., 57 Holborn Viaduct, London, October, 1882, by T. A. Fleming, R. S. E., actual working conditions with light load.

| | |
|---|---|
| Welsh coal. | |
| Duration of test in hours, | 13.5 |
| Average steam pressure, | 66.66 |
| Average temperature of feed, | 130 |
| Water evaporated in pounds, | 34,800 |
| Coal fired, " " | 3,360 |
| Per cent. of ash, | 7.5 |
| Combustible in pounds, | 3,108 |
| Grate-surface square feet, | 39.75 |
| Coal burned per sq. foot of grate, per hour, lbs., | 6.261 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 10.357 |
| " combustible " " " | 11.196 |
| " coal from and at 212°, " | 11.527 |
| " combustible " " | **12.46** |
| Rated horse-power, | 146 |
| Horse-power developed, | 119.9 |
| Per cent. *below* rated capacity, | 23.3 |

Test of a Babcock & Wilcox boiler, made at the Sugar Refinery of McEachran, Adam & Co., Greenock, Scotland, November, 1882.

| | |
|---|---|
| Scotch coal. | |
| Duration of test in hours, | 4 |
| Average steam pressure, | 36 |
| Average temperature of feed, | 156 |
| Water evaporated in pounds, | 10,426 |
| Coal fired, " " | 1,344 |
| Per cent. of ash, | 7 |
| Combustible in pounds, | 1,250 |
| Grate-surface, square feet, | 25 |
| Coal burned per sq. foot of grate, per hour, lbs., | 13.44 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 10.73 |
| " combustible " " " | 11.53 |
| " coal from and at 212°, " | 11.52 |
| " combustible " " | **12.38** |
| Rated horse-power, | 122 |
| Horse-power developed, | 129 |
| Per cent. above rated capacity, | 5.7 |

Test made at the Singer Mfg. Co.'s shops at Kilbowie, Scotland, May 26, 1884, by Frederic Leeders, superintending engineer.

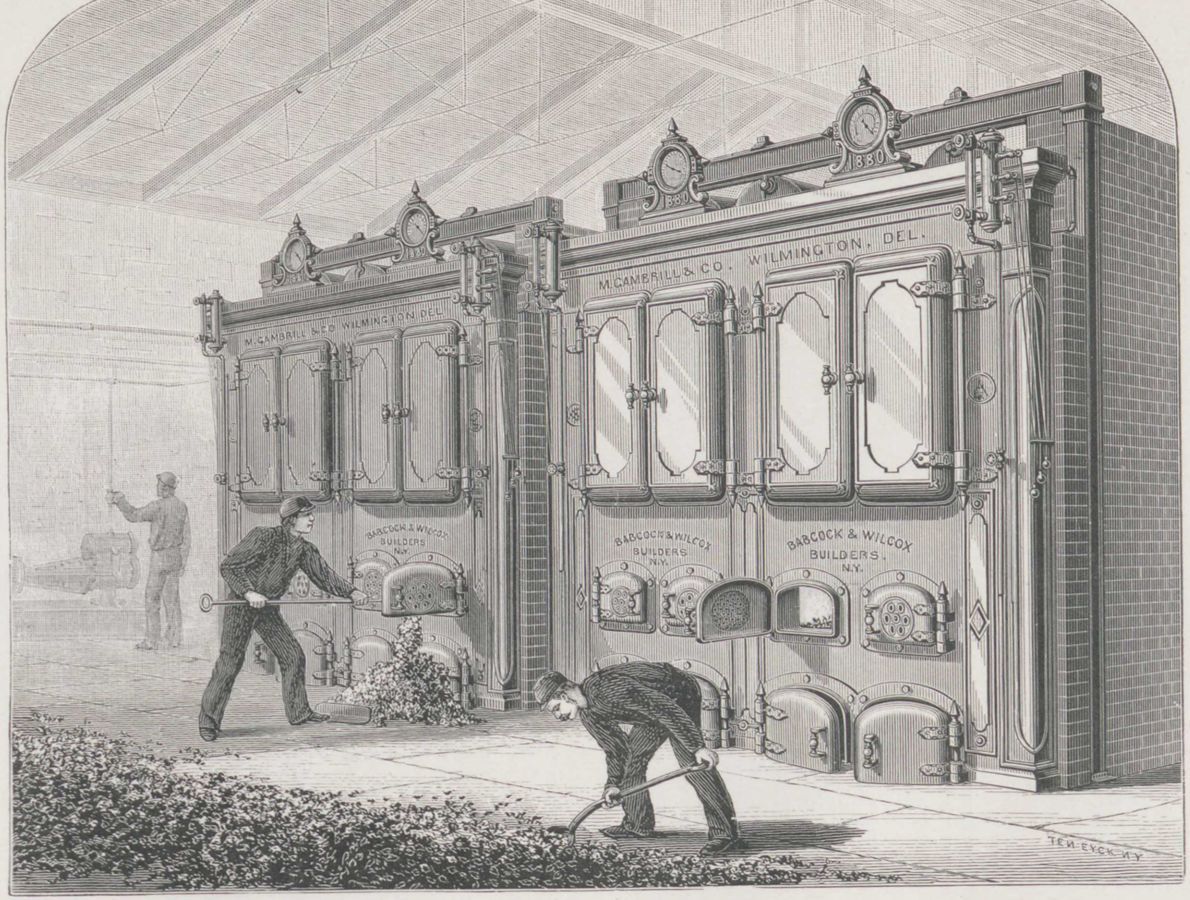
| | |
|---|---|
| Coal used Anchinraith, bituminous. | |
| Duration of test in hours, | 7 |
| Average steam pressure, | 65 |
| Average temperature of feed, | 141 |
| Pounds of coal burned, | 2,072 |
| Pounds of refuse, | 375 |
| Pounds of combustible, | 1,697 |
| Per cent. of ash, | 18.1 |
| Coal burned per sq. foot of grate, per hour, lbs., | 18.2 |
| Total water evaporated, in pounds, | 17,500 |
| Water evaporated: | |
| Per lb. coal—actual conditions, lbs., | 8,445 |
| " " from and at 212°, lbs., | 9.340 |
| " combustible, actual conditions, lbs., | 10.312 |
| " combustible from and at 212°, | **11.404** |
| Rated horse-power, | 51 |
| Horse-power developed, | 89.9 |
| Per cent. above rated capacity, | 76 |

Test of two Babcock & Wilcox boilers, made at Lehman Abraham & Co.'s New Orleans, La., June, 1884, by Frederic Cook, M. E.

| | |
|---|---|
| Coal used, Pittsburgh bituminous. | |
| Duration of test in hours, | 11 |
| Average steam pressure, | 98 |
| Average temperature of feed, deg. Fah., | 135 |
| Pounds of coal burned, | 12,162 |
| Pounds of refuse, | 664 |
| Pounds of combustible, | 11,498 |
| Per cent. of ash, | 5.4 |
| Coal burned per sq. foot of grate, per hour, lbs., | 18.02 |
| Water evaporated: | |
| Per sq. ft. heating surface, per hour, | 4.35 |
| " lb. coal—actual conditions, | 9,507 |
| " " " from and at 212°, | 10.628 |
| " " combustible, actual conditions, lbs., | 11.956 |
| " " combustible from and at 212°, | **11.243** |
| Rated horse-power, | 208 |
| Horse-power developed, | 379.2 |
| Per cent. above rated capacity, | 82.3 |
| Temperature in flue gases, | 520 |

Test of two Babcock & Wilcox boilers, made at Rockland Paper Mills, Wilmington, Del., May 14 and 15, 1884, by Wm. Kent, M. E.

| | |
|---|---|
| Coal, Wm. Penn, Schuylkill, anthracite. | |
| Duration of test, hours, | 24 |
| Average steam pressure by gauge, | 75.8 |
| Average temperature of feed water, deg. Fah., | 153.4 |
| Pounds of coal burned, | 15,197 |
| Pounds of refuse, | 2,101 |
| Pounds of combustible, | 13,096 |
| Per cent. of ash, | 13.20 |
| Coal burned per sq. foot grate, per hour, lbs., | 10.23 |
| Total water evaporated, | 139,059 |
| Water evaporated: | |
| Per lb. coal—actual conditions, lbs., | 8.737 |
| " " from and at 212°, lbs., | 9.576 |
| " combustible, actual condition, lbs., | 10.066 |
| " combustible, from and at 212°, | **11.626** |
| Quality of steam, per cent. moisture, | 0.61 |
| Draft in inches of water, | 0.16 |
| Rated horse-power, | 240 |
| Horse-power developed, | 204.9 |
| Per cent. below rated capacity, | 14.6 |
| Temperature of flue gases, degrees Fah. | 336 |




Babcock & Wilcox Boilers at M. Gambrill & Co's Cotton Mills, Wilmington, Del. 500 H. P. Erected 1880.

Test of four Babcock & Wilcox boilers at the Arlington Mills Mfg. Co.'s, Wilmington, Del., May 9, 1883, by Geo. H. Barrus, M. E.

Coal, anthracite pea, Sterling Mine, Shamokin region, Pa.

| | |
|---|---|
| Duration of test, in hours, | 11 |
| Average steam pressure, | 106.2 |
| Average temperature of feed, | 145.3 |
| Water evaporated in pounds, | 161,656 |
| Coal fired in pounds, | 19,043 |
| Per cent. of ash, | 17.4 |
| Combustible in pounds, | 15,726 |
| Grate-surface, square feet, | 141.68 |
| Coal burned per sq. ft. of grate, per hour, lbs., | 12.22 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 8.49 |
| " combustible " " " | 10.28 |
| " coal from and at 212°, " | 9.13 |
| " combustible, " " | **11.44** |
| Rated horse-power, | 488 |
| Horse-power developed, | 526 |
| Per cent. above rated capacity, | 7.7 |

Test of two Babcock & Wilcox boilers, made at the Peacedale Mfg. Co., Peacedale, R. I., Dec., 1882, by Geo. H. Barrus, M. E.

Coal, ¾ Powelton bituminous, ¼ anthracite screenings.

| | |
|---|---|
| Duration of test, in hours, | 10.25 |
| Average steam pressure, | 77.50 |
| Average temperature of feed, | 38 |
| Water evaporated, in pounds, | 133,096 |
| Coal fired, in pounds, | 14,287 |
| Per cent. of ash, | 8.8 |
| Combustible, in pounds, | 13,025 |
| Grate-surface, square feet, | 70 |
| Coal burned per sq. foot of grate, per hour, lbs., | 20 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 9.32 |
| " combustible " " " | 10.22 |
| " coal from and at 212°, " | 11.32 |
| " combustible " " | **12.42** |
| Rated horse-power, | 284 |
| Horse-power developed, | 447.70 |
| Per cent. above rated capacity, | 57 |

Test of three Babcock & Wilcox boilers at the Arlington Mills Mfg. Co.'s, Wilmington, Del., May 10, 1883, by Geo. H. Barrus, M. E.

Coal, anthracite pea, Sterling Mine, Shamokin, Pa.

| | |
|---|---|
| Duration of test, in hours, | 11 |
| Average steam pressure, | 105.4 |
| Average temperature of feed, | 156.7 |
| Water evaporated, in pounds, | 155,767 |
| Coal fired, in pounds, | 18,371 |
| Per cent. of ash, | 15.8 |
| Combustible, | 15,470 |
| Grate-surface, square feet, | 106.26 |
| Coal burned per sq. ft. of grate, per hour, lbs., | 15.72 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 8.48 |
| " combustible " " " | 10.07 |
| " coal from and at 212°, " | 9.01 |
| " combustible " " | **11.08** |
| Rated horse-power, | 366 |
| Horse-power developed, | 502.1 |
| Per cent. above rated capacity, | 37.1 |

Test of two Babcock & Wilcox boilers, made at Miami Soap and Oil Works, Cincinnati, O., August, 1882, by J. W. Hill, M. E.

Coal, Pittsburgh *slack*, burned with force blast.

| | |
|---|---|
| Duration of test, | 8 |
| Average steam pressure, | 51.72 |
| Average temperature of feed, | 74.016 |
| Water evaporated, lbs., | 51,220.79 |
| Coal fired, " | 7,365 |
| Per cent. of ash, | 12.31 |
| Combustible, lbs., | 6,460 |
| Grate-surface, | 49.833 |
| Coal burned per sq. foot of grate, per hour, lbs., | 14.77 |
| Water evaporated: | |
| Per lb. coal under actual conditions, | 6.954 |
| " combustible, " " | 7,928 |
| " coal from and at 212°, | 8.136 |
| " combustible " | **9.236** |
| Rated horse-power, | 146 |
| Horse-power developed, | 249.69 |
| Per cent. above rated capacity, | 71 |

Test made at the Am. Grape Sugar Co., Buffalo, Jan. 20, 1885, on a Babcock & Wilcox boiler erected July, 1878, by Edwin Roat, Chief Eng.

Bituminous coal, Pittsburgh.

| | |
|---|---|
| Duration of test in hours, | 10 |
| Average steam pressure by gauge, | 68.97 |
| Average temperature of feed water, | 121.42 |
| Pounds of coal burned, | 15,065 |
| Pounds of combustible, | 13,700 |
| Per cent. of ash, | 9.06 |
| Coal burned per square ft. grate, per hour, lbs., | 15 |
| Total water evaporated at temp. of feed, " | 143,683 |
| Water evaporated: | |
| Per sq. ft. heating surface, per hour, lbs., | 4.11 |
| " lb. coal—actual conditions, " | 9.53 |
| " " " —from and at 212°, " | 10.88 |
| " combustible actual conditions, lbs., | 10.48 |
| " combustible from and at 212°, lbs., | **11.97** |
| Rated horse-power, | 300 |
| Horse-power developed, | 529.4 |
| Per cent. above rated capacity, | 76.4 |

Test of two Babcock & Wilcox boilers, made at the Mill Creek Distillery, Cincinnati, O., by J. W. Hill, M. E., September, 1882.

Coal, Pittsburgh lump, 3d pool.

| | |
|---|---|
| Duration of test in hours, | 10 |
| Average steam pressure, | 63.975 |
| Average temperature of feed, | 132 |
| Water evaporated, in pounds, | 112,663.455 |
| Coal fired, in pounds, | 12,000 |
| Per cent. of ash, | 4.81 |
| Combustible, in pounds, | 11,421.75 |
| Grate-surface, square feet, | 43.5 |
| Coal burned per sq. foot of grate, per hour, lbs., | 27.5 |
| Water evaporated: | |
| Per lb. coal under actual conditions, lbs., | 9.388 |
| " combustible, " " " | 9.863 |
| " coal from and at 212°, " | 10.467 |
| " combustible " " | **10.997** |
| Rated horse-power, | 240 |
| Horse-power developed, | 418.7 |
| Per cent. above rated capacity, | 74.4 |

TABLE OF THIRTY TESTS OF BABCOCK & WILCOX WATER-TUBE BOILERS.

| Number of Tests. | NAME OF TEST. | WHERE MADE. | DATE. | NAME OF ENGINEER CONDUCTING TEST. | Duration of Test in hours. | Total combustible consumed. | Total water evaporated from and at 212° F. | Pounds of combustible burned per hour per sq. ft. of surface. | Pounds of combustible burned per hour per sq. ft. of grate. | Water evaporated per pound of combustible from and at 212°. | Per cent. of moisture in steam. | Horse-power of boilers as rated. | Actual Horse-power = 30 lbs. water evaporated per hour from 100° at 70 lbs. pressure. | Per cent. of Rankine's "standard." | Per cent. theoretical evaporation practical with anth. coal. | KIND OF COAL USED. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | U. S. Centennial | Philadelphia, Pa | 1876 | Emery, Porter & Bel- | 8. | 3,164.55 | 38,469.5 | .256 | 8.885 | 12.131 | 2.67 | 150. | 135.59 | 99.2 | 96.3 | Anthracite. |
| 2 | Harrison, Havemeyer & Co. | " " | Jan...1879 | Peter Ehlers.. [knap. | 120. | 68,297.5 | 793,620.1 | .260 | 11.21 | 11.620 | No test. | 187. | 194.60 | 95.5 | 92.4 | " (Buckwheat.) |
| 3 | Raritan Woolen Mills | Raritan, R. I. | Feb..1879 | Chas. E. Emery | 12.4 | 16,416. | 184,204. | .324 | 12.87 | 11.221 | 1.045 | 360. | 464.00 | 94.9 | 91 1 | " |
| 4 | Thos. A. Edison, Lab'tory. | Menlo Park, N. J. | Jan...1881 | Chas. L. Clarke | 12. | 2,416. | 29,695. | .294 | 8.11 | 11.360 | .000 | 75. | 73.00 | 94 4 | 91.3 | " |
| 5 | Miami Soap Works | Cincinnati, O | July..1882 | John W. Hill | 8. | 6,460. | 59,923.2 | .488 | 16.2 | 9.136 | 3.258 | 146. | 221.17 | 82.7 | 78.7 | Pittsburgh slack. |
| 6 | Mill Creek Distillery | " " | Sept..1882 | " " " | 10. | 11,421.75 | 124,549. | .415 | 26.17 | 10.997 | 4.616* | 240. | 370.84 | 96.6 | 92.2 | " 3 Pool. |
| 7 | Brush Electric Light Co. | Philadelphia, Pa. | Oct..1882 | J. C. Hoadley | 21 5 | 12,114.5 | 140,734. | .354 | 12.25 | 11.617 | 3.15 | 146. | 193.20 | 99.4 | 95.3 | Anthracite. |
| 8 | Edison Electric Light Co. | London, England. | Oct..1882 | J. A. Fleming, R.S.E. | 13.5 | 3.108. | 38,835.8 | .137 | 5.80 | 12.495 | "Dry" | 146. | 84.93 | 97.1 | 100.0 | Welsh (bit.) |
| 9 | McEachran, Adams & Co. | Greenock, Scotland. | Nov..1882 | Chas. A. Knight | 4. | 1,250. | 15,475. | .276 | 12.41 | 12.380 | No test. | 122. | 118.04 | 102.6 | 98.8 | Scotch " |
| 10 | American Inst. Fair | New York, N. Y. | Nov..1882 | Jas. E. Denton | 8.25 | 5,096.5 | 55,432.19 | .220 | 8.82 | 10.870 | "Dry" | 250. | 198.38 | 87.4 | 85.4 | Anthracite. [dust. |
| 11 | Peacedale Mfg. Co. | Peacedale, R. I. | Dec..1882 | Geo. H. Barrus | 10.25 | 13,025. | 161,771. | .406 | 18.15 | 12.420 | " | 280. | 465.64 | 108.1 | 103.8 | ¾ Semi-bit, ¼ ant. |
| 12 | Genesee Mills | San Francisco, Cal. | Feb..1883 | A. Worthington | 7.4 | 3,263. | 38,851.2 | .282 | 20.75 | 11.910 | No test. | 136. | 151.90 | 98.8 | 95.3 | Cardiff Wales, (bit.) |
| 13 | " " | " " | Feb..1883 | " " | 6.6 | 3,493. | 36,414. | .342 | 24.90 | 10.420 | " | 136. | 164.55 | 88.8 | 85.1 | Wash. Ter. (bit.) |
| 14 | " " | " " | Feb..1883 | " " | 6.3 | 3,156.5 | 34,041.46 | .326 | 23.58 | 10.796 | " | 136. | 159.65 | 91.3 | 87.7 | Wellington, B. C., |
| 15 | Benedict & Burnham | Waterbury, Conn. | Mar..1883 | Wm. E. Crane | 22. | 18,626. | 212,977. | .307 | 14.25 | 11.430 | 1.81 | 250. | 285.59 | 95.9 | 92.2 | Anthracite. [ (bit.) |
| 16 | Oliver Roberts Wire W'ks. | Pittsburgh, Pa. | Mar..1883 | Wm. Kent | 114. | 169,303. | 1,865,107. | .331 | 21.72 | 10.909 | No test. | 416. | 478.37 | 92.4 | 88.7 | Pittsburgh, (bit.) |
| 17 | McGinnis Cotton Mills | New Orleans, La. | Mar..1883 | Fred'k Cook | 8. | 6,171. | 68,453. | .215 | 8.38 | 11.090 | " | 312. | 265.60 | 89.3 | 87.0 | " |
| 18 | Arlington Cotton Mills | Wilmington, Del. | May.1883 | Geo. H. Barrus | 11. | 15,726. | 179,825. | .280 | 10.09 | 11.440 | "Dry" | 488. | 481.80 | 94 8 | 91.5 | Shamokin, (anthra.) |
| 19 | " " " | " " | May..1883 | " " " | 11. | 15,420. | 171,495. | .334 | 13.23 | 11.080 | " | 366. | 459.30 | 94.0 | 90.3 | " |
| 20 | Cambria Iron Co. | Pittsburgh, Pa. | May..1883 | Wm. H. Smith | 7.75 | 4,620. | 58,643.2 | .190 | 11.69 | 12.690 | No test. | 272. | 225.50 | 101.0 | 99.6 | Semi-bit. slack. |
| 21 | Harrison, Havemeyer & Co. | Philadelphia, Pa | Nov..1883 | Wm. Kent | 72. | 41,102. | 447,490.4 | .266 | 11.13 | 10.884 | 1.81 | 187. | 185.70 | 89.7 | 86.7 | Anth., Buckwheat. |
| 22 | Singer Mfg. Co. | Kilbowie, Scotland. | Mar..1884 | Geo. W. Thode | 4.5 | 1,596. | 17,400.4 | .332 | 15.353 | 10.903 | No test. | 93. | 111.17 | 92.4 | 88.8 | Bit.dross 6/3 per ton |
| 23 | Harrison, Havemeyer & Co. | Philadelphia, Pa | April.1884 | C. A. Brinley | 216. | 135,631,8 | 1,625,131.25 | 292 | 12.22 | 11.982 | "Dry" | 187. | 228.90 | 99.9 | 96.2 | Anth., Buckwheat. |
| 24 | Rockland Mills. | Wilmington, Del. | May..1884 | Wm. Kent | 24. | 13,096. | 152,895.4 | .198 | 8.82 | 11.626 | 0.61 | 240. | 187.50 | 92.9 | 91.0 | Anthracite. |
| 25 | Lehman, Abrahams & Co. | New Orleans, La. | May..1884 | Fred'k Cook | 11. | 11,498. | 129,384.4 | 432 | 17.27 | 11.253 | No test. | 208. | 347.00 | 99.7 | 95.1 | Pittsburgh, (bit.) |
| 26 | Singer Mfg. Co | Kilbowie, Scotland. | May..1884 | Fred'k Leiders | 7. | 1,697. | 19,353. | .414 | 14.92 | 11.404 | " | 51. | 82.26 | 100.1 | 95.6 | Scotch, " |
| 27 | Grant Mills | Ransbottom, Eng. | July..1884 | Hepburn & Co. | 8. | 5,194. | 57,023.2 | .415 | 21.64 | 10.991 | " | 136. | 212.50 | 96.8 | 92.2 | " dross 5/ per ton |
| 28 | Singer Mfg. Co. | Kilbowie, Scotland. | Oct..1884 | Fred'k Leiders | 4. | 1,443. | 14,320.20 | .629 | 40 00 | 9.924 | "Dry" | 51. | 105.50 | 94.9 | 90.0 | " " |
| 29 | American Glucose Co | Buffalo, N. Y. | Jan..1885 | Edwin Roat | 10. | 13,700. | 161,931. | .392 | 13.7 | 11.820 | No test. | 300. | 469.00 | 102.8 | 98.3 | Pittsburgh, (bit.) |
| 30 | " " " | " " | Mar..1885 | " " | 10. | 4,440. | 56,053. | .161 | 6.33 | 12.620 | " | 250. | 162.00 | 99.1 | 100.2 | " " |
| | Totals. | | | | 788.45 | 611,946.1 | 6,989,497.9 | | | | | 6,317. | 7.313.18 | | | |
| | Averages by arithmetical means | | | | | | | .319 | 15.028 | 11.381 | | | | 95.75 | 92.34 | |
| | Averages by calculations from totals | | | | | | | .324 | | **11.4217** | | | | **96.50** | **92.85** | |

* This is the highest percentage of moisture reported from any test of these boilers. The same engineer using same apparatus reported 5.33 per cent. of moisture in steam from two-flue boilers while evaporating only 1.95 lbs. water per hour per square foot of heating surface.

# AVERAGE COST OF REPAIRS

## OF BABCOCK & WILCOX BOILERS IN THE PAST SEVENTEEN YEARS.

*The following facts are gathered from a large number of answers to a circular of inquiry sent to all our older customers. Sufficient replies were received to include over 100,000 horse-power, the repairs to the heating surface of which, due to all causes, have averaged less than 5 cents per horse-power per year, of 300 days at 12 hours per day; boilers which have run night and day being credited with the extra running time. The list would have been more complete, and made a still better showing but for the fact that a number of our best customers declined to give facts pertaining to their business for publication.*

DECASTRO & DONNER SUGAR REFINING CO., 2880 H. P. Average time, 13.6 years, night and day. Total repairs, 6c. yearly per H. P.

SINGER MANUFACTURING CO. (Case Factory), South Bend, Ind., 900 H. P. Average time, $12\frac{1}{3}$ years. Total repairs, $\frac{4}{10}$c. yearly per H. P.

"Very bad feed-water.....carry heavy fires and force them beyond their rated capacity......in one instance we had to replace two heads and four tubes that were broken and blistered by a careless fireman *heating an empty boiler red hot, and then turning on the feed water!!* Instead of a disastrous explosion that would have followed with other boilers, we lost the above parts and two days' time." LEIGHTON PINE, Manager.

AMERICAN GLUCOSE CO., Buffalo, N. Y. 3050 H. P. Average time, 9.8 years. Total repairs, 4c. yearly per H. P.

NEW YORK STEAM CO. 13900 H. P. Average time, 3.92 years, night and day. Total repairs, ¾c. yearly per H. P.

ROSAMOND WOOLEN CO., Almonte, Ont. 360 H. P. Average time, $8\frac{1}{3}$ years. Total repairs, $1\frac{1}{10}$c. yearly per H. P.

BOUND BROOK WOOLEN MILLS. 600 H. P. Average time, 8.1 years. Total repairs 2c. yearly per H. P.

RARITAN WOOLEN MILLS. 1060 H. P. Average time, 6.7 years. Total repairs, *nothing*.

E. C. KNIGHT & CO., Philadelphia. 2000 H. P. Average time, 5¼ years. Total repairs, 1c. yearly per H. P.

CONGLOMERATE MINING CO. 1800 H. P. Average time, 3 years. Total repairs, *nothing*.

"The boilers in every way come up to our highest expectations." HENRY C. DAVIS, Pres't.

BOSTON SUGAR REFINING CO. 1250 H. P. Average time, 8½ years. Total repairs, $4\frac{1}{10}$c. yearly per H. P.

"Were put in early in 1880; have been in constant use night and day ever since."

C. GILBERT, Des Moines, Iowa. 488 H. P. Average time, 5 years. Total repairs, $3\frac{2}{10}$c. yearly per H. P.

BROOKLYN SUGAR REFINING CO. 3464 H. P. Average time, 7⅓ years, running night and day. Total repairs, 1¼c. yearly per H. P.

JOHN CROSSLEY & SONS, LIMITED, Plantation, Louisiana. 1260 H. P. Average time, 3⅓ years. Total repairs, *nothing*.

PORTAGE STRAW BOARD CO., Circleville, O. 1472 H. P. Average time, $3\frac{1}{3}$ years. Total reparis, $3\frac{9}{10}$c. yearly per H. P.

"These boilers have been worked hard a great portion of time and have given good satisfaction." JNO. L. TAFLIN, Manager.

BAY STATE SUGAR REFINING CO., Boston. 798 H. P. Average time, 7.3 years. Total repairs, $\frac{7}{10}$c. yearly per H. P.

"These boilers have been constantly driven at their highest capacity ever since their installation, until the present winter, and the cost of repairs to heating surfaces in that time has been $82.53." J. F. STILLMAN, Supt.

WHEELER, MADDEN & CLEMSEN M'F'G. CO. Middletown, N. Y. 244 H. P. Average time, 5 years. Total repairs, *nothing*.

"We think this a very good record, and are very much pleased with the boilers."

JOEL H. GATES, Burlington, Vt. 244 H. P. Average time, 5 years. Total repairs, *nothing*.

RUMFORD CHEMICAL WORKS. 279 H. P. Average time, 5 years. Total repairs, *nothing*.

"No expense on account of repairs to heating surfaces for either of them, since they were put in." N. D. ARNOLD, Treas.

TYTUS PAPER CO., Middletown, O. 650 H. P. Average time, 6 years, night and day. Total repairs, 6½c. yearly per H. P.

SOLVAY PROCESS CO., Syracuse, N. Y. 3456 H. P., from 6 to 1½ years. Average time, 2.6 years, night and day. Total repairs, 1½c. yearly per H. P.

"The only repairs we have had to make are for new tubes when they have been burnt out. As you are well aware the water which we use at Syracuse is very hard upon boiler tubes, and we suppose we have burnt out more on this account than if the water had been good." F. R. HAZARD, Treas.

"I believe our repairs would have been greater had we used the tubular type of ordinary design." W. B. COGSWELL, Manager.

THE WARDLOW THOMAS PAPER CO., Middletown, O. 600 H. P. Average time, 6 years. Total repairs, *nothing*.

"Easily managed, economical in coal, attendance and repairs; and the element of safety under our hard firing is a source of much satisfaction to us." O. H. WARDLOW, Pres't.

W. A. WOOD, M. &. R. M. CO. 360 H. P. Average time, $4\frac{6}{10}$ years. Total repairs, $1\frac{2}{10}$c. yearly per H. P.

"We consider them as good as new to-day, and can recommend them as economical both in repairs and fuel.' J. M. ROSEBROOKS, Sup't.

MARCUS MOXHAM & CO., Swansea, Wales. 104 H. P. Average time, 3¾ years.

"It has not cost us a penny for repairs."

LAING, WHARTON & DOWN, *Electricians*, London. 85 H. P. Average time, 2.3 years.

"As regards repairs they have got to come, as they have not yet cost anything."

CARNEGIE BROTHERS & CO., Pittsburgh, 900 H. P. Average time, 5 years. Total repairs, $1\frac{1}{10}$c. yearly per H. P.

"The total repairs to heating surfaces in that time has been $50." CARNEGIE BROS. & CO.

RANSOMES, SIMS & JEFFERIES, L'd., Ipswich, England. 35 H. P. Average time, 4½ years, Total repairs, *nothing*.

"The repairs appear to have been about £7 for brick-work." RANSOMES, SIMS & JEFFERIES, L'D.

CROCKER CHAIR CO., Sheboygan, Wis. 225 H. P. Average time, 7 years. Total repairs, 1c. yearly per H. P.

"The total cost of repairs to heating surfaces in that time has been not to exceed $15. We do not hesitate to say that it is the best boiler we have ever used."

EAGLE PAPER CO., Franklin, O. 250 H. P. Average time, 4¾ years. Total repairs, 22c. yearly per H. P.

"We are well pleased with them."
D. B. ANDERSON, Manager.

FIELDHOUSE & DUTCHER MANUFACTURING CO. Chicago, 75 H. P. Average time, 6 years. Total repairs, $11\frac{1}{10}$c. yearly per H. P.

"Consider your boiler to be the most economical and best made."

LOUISIANA SUGAR REFINING CO. 960 H. P. Average time, 5½ years.

"The cost of repairs is very moderate."
JOHN S. WALLIS, Pres't.

NORTH BEND PLANTATION, Louisiana. 400 H. P. Average time, 10 years. Total repairs, 11¼c. yearly per H. P.

FRANCIS AXE CO. 136 H. P. Average time, $5\frac{3}{10}$ years. Total repairs, *nothing*.

WELHAM ESTATE, Louisiana. 240 H.P. Average time, 2 years. Total repairs, *nothing*.

"I have used the boiler with perfect satisfaction."
WM. E. BRICKELL, Agent.

JOSEPH SCHOFIELD & CO. Littleborough, Manchester. 156 H. P. Average time, 2¾ years. Total repairs, 1½c. yearly per H. P.

SETH THOMAS CLOCK CO. 125 H. P. Average time, 7 years. Total repairs, *nothing*.

"The only cost has been the amount spent on account of burning up of fire-box furnace brick."

WALLACE & SONS. 400 H. P. Average time, 7 years. Total repairs, $\frac{7}{10}$c. yearly per H. P.

"They are apparently in perfect condition now."

FOOS & BARNETT. 125 H. P. Average time, 7 years. Total repairs, *nothing*.

"Have not cost one dollar for repairs—simply new grate bars. Think they are good economical boilers."

CORTLAND WAGON CO. 82 H. P. Average time, 6 years. Total repairs, *nothing*.

"No outlay for repairs. We consider this remarkable because we have forced the boiler from the beginning."

EAGLE SQUARE MANUFACTURING CO., South Shaftsbury, Vt. 200 H. P. Average time, 5½ years. Total repairs, *nothing*.

"Have purchased a few fire brick to go between tubes. We have found no other repairs necessary."
F. L. MATTISON, Treas.

PAINE LUMBER CO., Oskosh, Wis. 416 H. P. Average time, 4 years. Total repairs, *nothing*.

"Have been using the ordinary boilers with both large and small tubes for thirty years past, and regard your boilers as more economical."
PAINE LUMBER CO.—A. B. Ideson.

P. P. MAST & CO., Springfield, O. 85 H. P. Average time, 8½ years, night and day. Total repairs, $3\frac{4}{10}$c. yearly per H. P.

"We regard it as the best boiler ever used by our Company, and think it has no equal in the market. After all this hard usage equal to 14 years, we find it still in good condition." P. P. MAST & CO.

EDISON ELECTRIC ILLUMINATING CO. of Piqua. O. 100 H. P. Average time, $5\frac{1}{3}$ years. Total repairs, $4\frac{7}{10}$c. yearly per H. P.

HALLET & DAVIS CO., Boston. 104 H. P. Average time, 6 years. Total repairs, 5c. yearly per H. P.

"Our repairs to boiler have been for new nipples in mud-drum in Aug., 1887, which is certainly a very creditable showing." HALLET & DAVIS CO.

H. D. SMITH & CO., Plantsville, Conn. 75 H. P. Average time, 8 years. Total repairs, *nothing*.

"We know of no other boiler that would do the work that this is doing." H. D. SMITH & CO.

F. A. POTH BREWING CO., Philadelphia. 400 H. P. Average time, 4 years. Total repairs, $1\frac{3}{10}$c. yearly per H. P.

J. L. CLARK, Oshkosh, Wis. 107 H. P. Average time, 6½ years. Total repairs, $\frac{7}{10}$c. yearly per H. P.

"Develop at least one-third more work than rated. We cannot speak too highly of your boilers. They are simply perfect." J. L. CLARK.

SOCIETÀ GENERALE ITALIANA DI ELETTRICITA, SISTEMA EDISON, Milan, Italy. 1476 H. P. Average time, 3½ years.

"The repairs have consisted in the changing of 4 tubes and about 220 rivets (not counting the last accident due to carelessness of the firemen")."
L'Amministratore Delegato—J. COLUMBA.

UNION IRON WORKS, Johnstone, Scotland. 104 H. P. Average time, 5 years. Total repairs, 3c. yearly per H. P.

P. & P. CAMPBELL, Perth, Scotland. 146 H. P. Average time, 2 years.

"The boilers have cost nothing for repairs themselves, but the doors and furnace have cost about £4. 10s. per annum." P. & P. CAMPBELL.

CHENEY BROS., So. Manchester, Conn. 350 H. P. Average time, 7 years.

"Running steadily for seven years, and during that time they have not cost us anything for repairs to the heating surfaces." CHENEY BROS.

TOLEDO & OHIO CENTRAL R. R. 120 H. P. Average time, $7\frac{2}{3}$ years. Total repairs, $12\frac{8}{10}$c. yearly per H. P.

"The boilers have given entire satisfaction in every respect." J. B. MORGAN, Master Mechanic.

MCAVOY BREWING CO., Chicago. 832 H. P. Average time, 6 years. Total repairs, 10c. yearly per H. P.

"Our experience with them has been to our entire satisfaction" GEO. DICKINSON, Sec'y.

(NOTE.—One-half of total expense was due to broken headers caused by low water, because of water combination becoming shut off.)

CORNWALL BROS., Lexington, Ky. 227 H. P. Average time, $8\frac{1}{4}$ years. Repairs, *nothing*.

MAGINNIS COTTON MILL, New Orleans. 624 H. P. Average time, 6 years. Total repairs, $1\frac{6}{10}$c. yearly per H. P.

PIONEER MILLS. 150 H. P. Average time, $9\frac{1}{3}$ years. Total repairs, "slight."

"Cost of repairs comparatively nothing. No leaking of flues or boiler at any time."
J. A. M. JOHNSTON, Agent.

LAWRENCE ROPE WORKS, Brooklyn. 250 H. P. Average time, 7 years. Total repairs, 4c. yearly per H. P.

JAMES MARTIN & CO., Philadelphia. 208 H. P. Average time, $7\frac{3}{10}$ years. Total repairs, 16c. yearly per H. P.

"There has been but little cost for repairs to them: those we have made being for a few new tubes that became clogged or coated with scale on account of the *very* hard (*well*) water we are using. We cannot speak too highly of them." JAS. MARTIN & CO.

FAIRMOUNT WORSTED MILLS, Philadelphia. 400 H. P. Average time, 7.5 years. Total repairs, $6\frac{8}{10}$c. yearly per H. P.

WM. WHITAKER & SONS, Philadelphia. 480 H. P. Average time, 7 years. Total repairs, *nothing*.

VANDERBILT UNIVERSITY, Nashville, Tenn. 200 H. P. Average time, 6 years. Total repairs, 4c. yearly per H. P.

"Cost of repairs to heating surface on all the above during that time has been $48.25. The boilers during that time have given entire satisfaction."
OLIN H. LANDRETH, Dean of Engineering Dep't.

ARLINGTON MILLS MANUFACTURING CO. 500 H. P. Average time, 8 years. Total repairs, *nothing*.

SOMERSET MANUFACTURING CO., Raritan, N. J. 720 H. P. Average time, 7.5 years. Total repairs, *nothing*.

NEW YORK & BROOKLYN BRIDGE. 600 H. P. Average, $2\frac{1}{3}$ years. Total repairs, *nothing*.

"The boilers have done excellent service and have given entire satisfaction." C. C. MARTIN, Ch. Eng. & Sup't.

CHURCH & CO., Brooklyn, E. D. 584 H. P. Average time, 4.2 years. Repairs, *nothing*.

ECONOMIST PLOW CO., South Bend, Ind. 150 H. P. Average time, 5 years. Total repairs, *nothing*.

"We believe it to be the most durable boiler made."
LEIGHTON PINE, Pres't.

UNION METALLIC CARTRIDGE CO., Bridgeport, Conn. 276 H. P. Average time, $4\frac{1}{3}$ years. Total repairs, *nothing*.

"The cost of repairs to heating surfaces of said boilers in that time has been nothing. We carry from 75 to 80 lbs. all the time." A. C. HOBBS, Sup't.

WARDER, BUSHNELL & GLESSNER CO. 650 H. P. Average time, $3\frac{1}{4}$ years. Total repairs, $4\frac{6}{10}$c. yearly per H. P.

"The boilers are giving us the best satisfaction."
CHAS. A. BAUER, Gen'l Manager.

CHICAGO CITY RAILWAY CO. 1000 H. P. Average time, 7 years, night and day. Total repairs, $4\frac{8}{10}$c. yearly per H. P.

"The boilers have worked well and proved very satisfactory." C. B. HOLMES, Sup't.

SHEBOYGAN MANUFACTURING CO. 333 H. P. Average time, 8 years. Total repairs, 4c. yearly per H. P.

"We have found them economical, easily kept in running order, and in all ways entirely satisfactory, and should we need additional power would use no other boilers." G. L. HOLMES, Pres't and Gen'l Manager.

JACKSON & SHARP CO., Wilmington, Del. 467 H. P. Average time, $5\frac{7}{10}$ years. Total repairs, $1\frac{7}{10}$c. yearly per H. P.

"Have cost *nothing* for repairs to heating surfaces, except through the carelessness of our fireman, who, soon after starting the first boilers, allowed the water to get too low and burst three or four headers, but doing no other damage. We consider them safe and economical steam generators."
THE JACKSON & SHARP CO., by Chas. S. Robb.

SOUTH BEND TOY MANUFACTURING CO. 61 H. P. Average time, 4 years. Total repairs, $2\frac{1}{2}$c. yearly per H. P.

"We consider these boilers the safest and most economical in the market." F. H. BADET, Sec. & Treas.

COLUMBUS BUGGY CO., Columbus, O. 800 H. P. Average time, 7 years. Total repairs, $1\frac{8}{10}$c. yearly per H. P.

"We consider them the best boiler in the market and we are now evaporating 9 lbs. of water to one pound of poor slack coal." FRED. WEADON, Sup't.

EDISON ELECTRIC ILLUMINATING CO. OF N. Y. 900 H. P. Average time, 7 years. Total repairs, *nothing*.

"They give plenty of dry steam and have been absolutely tight at all times. The boilers have shown unusual abillty to carry a constant pressure under the extreme and sudden fluctuations, which are unavoidable in an electric light station." C. E. CHINNOCK, V. Pres.

KENNESAW MILLS CO., Marietta, Ga. 200 H. P. Average time, 7 years. Total repairs, $2\frac{3}{10}$c. yearly per H. P.

"You will see that the repairs on our boilers have not cost very much for the last 7 years." J. R. BUCHANAN.

E. Greenfield's Son & Co., Brooklyn. 160 H. P. Average time, 4 years.

"They show no signs of wear, therefore probably will not need repairing for some time to come. We consider them the best boilers we have ever used."

Black & Germer, Erie, Pa. 92 H. P. Average time, 4 years. Total repairs, *nothing*.

"Is easily cared for and economical in the consumption of fuel."

Planters' Sugar Refining Co., New Orleans. 292 H. P. Average time, 6 years. Total repairs, *nothing*.

"The only expense attached to them has been new grate bars and fire brick work." John Barkley, Pres't.

S. S. Hepworth, Yonkers, N. Y. 104 H. P. Average time, $4\frac{5}{12}$ years.

"During all this time it gave no trouble whatever, and did not cost one penny for repairs."

Wilson & McCallay Tobacco Co. 300 H. P. Average time, 5 years. Total repairs, $4\frac{1}{3}$c. yearly per H. P.

John Collins, Denny, North Britain. 425 H. P. Average time, $3\frac{4}{10}$ years.

"The repairs to heating surfaces have been slight, and caused by an unfortunate admission of grease to feed water in the case of my 140 H. P. boiler. With this exception, which of course arose from no fault of yours, the boilers have done good and heavy work and given me satisfaction." John Collins.

Singer Manufacturing Co. Kilbowie, Scotland. 2106 H. P. Average time, $4\frac{1}{2}$ years. Total repairs, $\frac{1}{6}$c. yearly per H. P.

"We have much pleasure in sending you particulars of boilers as requested......Total repairs, £3.19.3, which we consider highly satisfactory."

Nova Scotia Sugar Refinery, Halifax, N. S. 800 H. P. Average time, $7\frac{3}{4}$ years, night and day. 600 H. P. since 1880; 200 in 1885. Total repairs, $1\frac{1}{2}$c. yearly per H. P.

"We have pleasure in saying we consider them first-class boilers in every respect." J. A. Turnbull, Man.

Kennedy's Patent Water Meter Co. L'd., Kilmarnock, Scotland. 51 H. P. Average time, 6 years. Total repairs, *nothing*.

"Repairs confined to re-expanding one tube. The cost was trifling." Thos. Kennedy.

Bent Colliery Co. L'd. Bothwell, Scotland. 480 H. P. Average time, $4\frac{8}{10}$ years.

"The cost of repairs during that time has been trifling. I think two short tubes were renewed. The boilers have been constantly at work." Jas. S. Dixon.

Corporation of Aberdeen Gas Works, Scotland. 93 H. P. Average time, 3 years, night and day. Total repairs, *nothing*.

"The boiler continues to give great satisfaction." Alex. Smith.

The Square Works, Ramsbottom, England. 136 H. P. Average time, 4 years, night and day. Total repairs, $9\frac{8}{10}$c. yearly per H. P.

"Since Feb. 5th, 1884, night and day work, 16/6 except the breakdown through being short of water, which cost £21.17.4 to repair." Hepburn & Co.

Whitmore & Sons, Edenbridge, Kent, England. 100 H. P. Average time, 3 years.

"Have not spent one penny on the boiler."

Miller & Co., Foundry, Edinburgh, Scotland. 240 H. P. Average time, 3 years. Total repairs, *nothing*.

"Only expense has been some repairs to the Brickwork in connection with the Stoker." Miller & Co.

Carthness Steam Saw Mill, Wick, Glasgow. 146 H. P. Average time, $2\frac{1}{2}$ years. Total repairs, *nothing*.

"We are well pleased with your boilers, and can with confidence recommend them to any firm wishing to economize their working expenses." Alex. McEwen.

Georgie Mills, Edinburgh, Scotland. 146 H. P. Average time, $3\frac{1}{2}$ years, night and day. Total repairs, *nothing*.

"Neither boiler has required any repairs to heating surfaces." J. & G. Cox.

J. & T. Boyd, Iron Works, Glasgow. 208 H. P. Average time, $2\frac{6}{10}$ years.

"One of these has worked nearly 5 years and the other about half that time without any repairs whatever."

Dubois & Charvet-Colombier, Armentières, France. 476 H. P. Average time, 3 years.

"These boilers have worked to our entire satisfaction since 2d November, 1885, without as yet any repairs whatever."

Arrol Brothers, Bridge Builders, Glasgow. 146 H. P. Average time, $5\frac{2}{3}$ years.

"Cost of repairs to heating surface is as yet nothing. It gives us pleasure to hand you this information, which is entirely at your own disposal." Arrol Bros.

James Eadie & Sons, Tube Works, Glasgow. 64 H. P. Average time, 5 years.

"Repairs to heating surfaces, none."

Hughes & Son. Meole Brace, Shrewsbury, England. 61 H. P. Average time, 4 years.

"Has up to now cost us nothing whatever for repairs. We can only repeat that we are very much pleased in every respect with your boiler."

Westinghouse Air Brake Co., Pittsburgh. 92 H. P. Average time, $4\frac{1}{2}$ years. Total repairs, 4c. yearly per H. P.

"The repairs have been merely nominal, being confined to the re-expanding of a few tubes and the replacing of two or three hand hole covers, at a total cost probably not exceeding $15. The boiler has given entire satisfaction." H. H. Westinghouse, General Manager.

Carthage Water Works. 122 H. P. Average time, $6\frac{1}{2}$ years. Total repairs, *nothing*.

"They are practically as good as when we put them in; there is not a blister or scale on the tubes. The fire has not been out since we first started up in January, 1882." C. S. Bartlett, Manager.

J. Pongs, Jr., Newerk, Germany. 120 H. P. Average time, 3 years.

"Has been running 3 years without needing any repairs up to this time." J. Pongs, Jr.

Carron Co., Carron, Stirlingshire, N. B. 416 H. P. Average time, 4 years. Total repairs, *nothing*.

# REFERENCES FOR BABCOCK & WILCOX BOILERS.

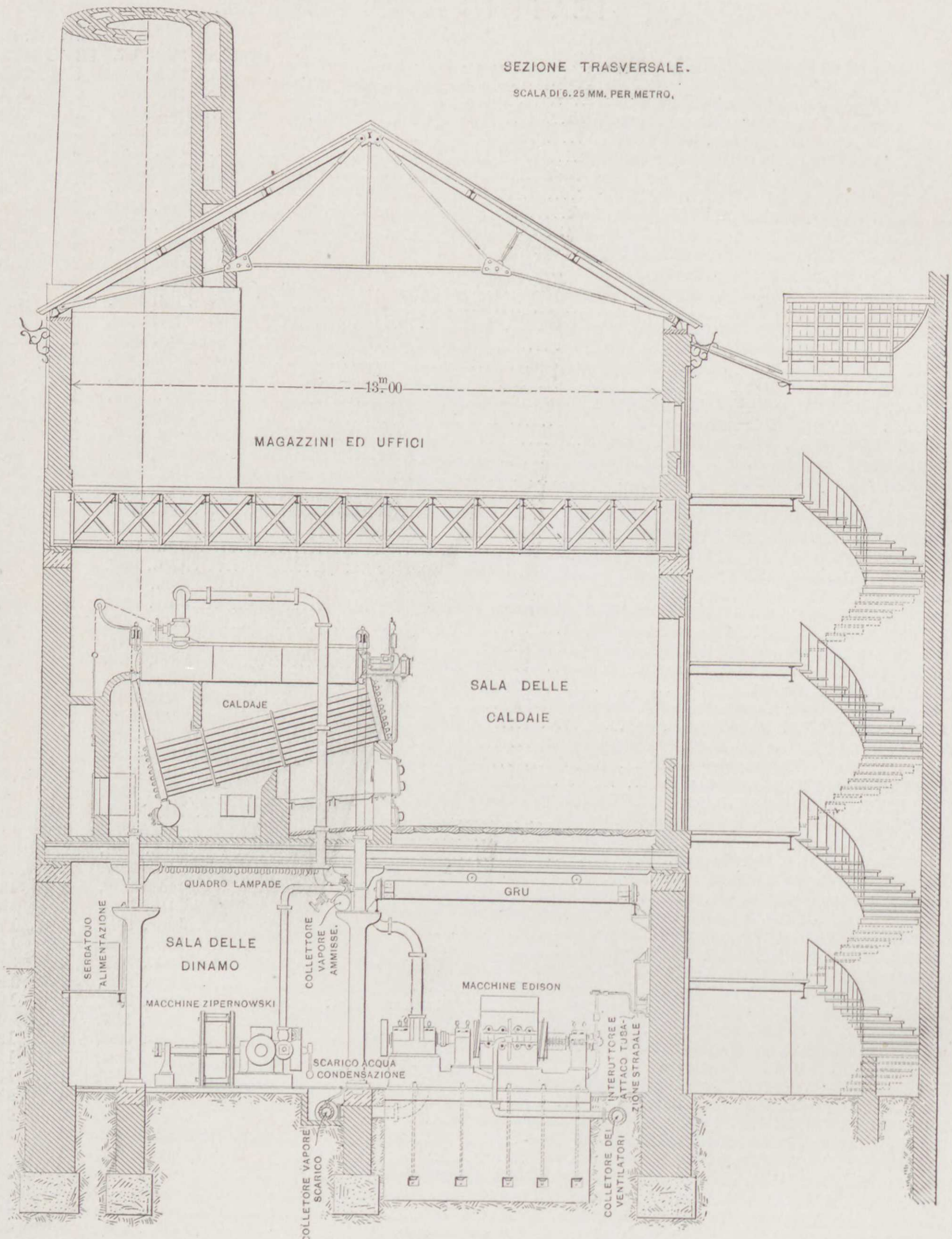
The following parties are among those to whom we have sold boilers in the past fifteen years. We would call particular attention to the numerous instances in which repeated orders have been given after years of use. This single fact tells more than volumes of certificates.

## STEAM HEATING AND POWER.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| NEW YORK STEAM COMPANY, New York | 14 orders 1880-1887, | 56 | 13482 |
| "VAN CORLEAR" (Apartment House), New York | 3 do 1878-1885, | 4 | 268 |
| "DAKOTA" (Apartment House), New York | 2 do 1882-1886, | 6 | 864 |
| "THE ALBANY" (Apartment House), New York | Sept., 1879, | 1 | 90 |
| "MADRID" (Apartment House), New York | May, 1883, | 2 | 122 |
| "BARCELONA" (Apartment House), New York | May, 1883, | 2 | 125 |
| COLUMBIA COLLEGE, School of Mines, New York, | 2 orders, 1879-1882, | 5 | 400 |
| COLLEGE OF THE CITY OF NEW YORK | Dec., 1884, | 1 | 35 |
| NEW YORK PRODUCE EXCHANGE, New York | Feb., 1884, | 3 | 624 |
| CONSOLIDATED STOCK & PETROLEUM EXCHANGE, New York | Oct., 1887, | 2 | 146 |
| MUTUAL LIFE INSURANCE COMPANY, New York | Mar., 1884, | 4 | 488 |
| AMERICAN INSTITUTE, New York | June, 1882, | 2 | 250 |
| NEW YORK HERALD, (Bennett Building), New York | Oct., 1884, | 2 | 244 |
| F. W. STILLMAN, New York | 2 orders, 1881-1882, | 2 | 150 |
| CORPORATION OF TRINITY CHURCH, New York | 2 do 1879-1882, | 3 | 160 |
| NURSERY AND CHILD'S HOSPITAL, New York | April, 1879, | 1 | 50 |
| DEPARTMENT OF DOCKS, Pier A, N. R., New York | 2 orders, 1885-1886, | 2 | 35 |
| PAREPA HALL, New York | 2 do 1883-1885, | 2 | 50 |
| ST. PAUL'S SCHOOL OF THE CATHEDRAL, Garden City, N.Y | Nov., 1884, | 1 | 104 |
| CORNELL UNIVERSITY, Ithaca, N. Y | 2 orders, 1885-1888, | 3 | 561 |
| CROUSE MEMORIAL COLLEGE, Syracuse, N. Y | July, 1888, | 2 | 208 |
| C. J. HAMLIN, Buffalo, N. Y | June, 1888, | 2 | 208 |
| RICHMOND HOTEL, Buffalo, N. Y | Aug., 1888, | 3 | 246 |
| EDMUND M. WOOD & CO., Nursery, Boston, Mass | Aug., 1882, | 1 | 50 |
| MASSACHUSETTS INSTITUTE of TECHNOLOGY, Boston, Mass | Apr., 1888, | 1 | 208 |
| WORCESTER POLYTECHNIC INSTITUTE, Worcester, Mass | July, 1888, | 1 | 51 |
| UNITED STATES NAVAL TRAINING STATION, Newport, R. I | Sept., 1884, | 2 | 122 |
| CENTRAL RAILROAD OF NEW JERSEY STATION, Jersey City, N. J | Oct., 1888, | 4 | 368 |
| TAYLOR'S HOTEL, Jersey City, N. J | Oct., 1881, | 1 | 50 |
| HAMBURG-AMERICAN PACKET COMPANY, Hoboken, N. J | July, 1882, | 2 | 208 |
| DR. ABRAM COLES BUILDING, Newark, N. J | July, 1885, | 1 | 107 |
| COUNTY OF UNION COURT HOUSE, Elizabeth, N. J | Oct., 1874, | 1 | 40 |
| COLLEGE OF NEW JERSEY, Princeton, N. J | April, 1879, | 1 | 30 |
| PUBLIC SCHOOL, Plainfield, N. J | May, 1883, | 1 | 35 |
| G. W. CHILDS (Public Ledger Building), Philadelphia, Pa | 2 orders, 1873-1882, | 3 | 150 |
| HOTEL LAFAYETTE, Philadelphia, Pa | 2 do 1872-1881, | 3 | 230 |
| GIRARD ESTATE, People's Bank, Philadelphia, Pa | Sept., 1876, | 1 | 50 |
| do do Various stores, etc | 5 orders, 1886-1888, | 7 | 638 |
| BINGHAM HOUSE, Philadelphia, Pa | May, 1885, | 2 | 80 |
| FIDELITY INSURANCE, TRUST & SAFE DEPOSIT COMPANY, Philadelphia, Pa | May, 1886, | 1 | 92 |
| SHARPLESS BROS., Dry Goods, Philadelphia, Pa | May, 1881, | 1 | 100 |
| WILLIAM WEIGHTMAN, Stores, Philadelphia, Pa | 2 orders, 1872-1877, | 6 | 410 |
| R. D. WOOD & SONS, Philadelphia, Pa | Aug., 1881, | 2 | 100 |
| PENNSYLVANIA RAILROAD COMPANY, General Offices, Phil'a, Pa., | 2 orders, 1883-1887, | 3 | 312 |
| GEO. S. HARRIS, Philadelphia, Pa | 2 do 1886-1887, | 2 | 120 |
| GLEN SUMMIT HOTEL & LAND COMPANY, Glen Summit, Pa | 2 do 1883-1884, | 2 | 60 |
| GEORGE WESTINGHOUSE, Jr., Pittsburgh, Pa | June, 1887, | 2 | 170 |
| WESTINGHOUSE BUILDING, Pittsburgh, Pa | Mar., 1888, | 3 | 152 |
| UNITED STATES CAPITOL, SENATE WING, Washington, D. C | Mar., 1887, | 2 | 312 |
| DEPARTMENT OF THE INTERIOR, Washington, D. C | June, 1888, | 2 | 122 |
| WESTERN LUNATIC ASYLUM, Staunton, Va | Sept., 1883, | 2 | 122 |
| LURAY CAVE & HOTEL COMPANY, Luray, Va | May, 1887, | 1 | 45 |
| HAMPTON NORMAL & AGRICULTURAL INSTITUTE, Hampton, Va | July, 1888, | 1 | 120 |
| H. I. KIMBALL HOUSE, Atlanta, Ga | Oct., 1884, | 2 | 120 |
| STATE LUNATIC ASYLUM, near Milledgville, Ga | Nov., 1887, | 1 | 136 |
| HOTEL PONCE DE LEON, St. Augustine, Fla | Apr., 1887, | 4 | 416 |
| CENTRAL KENTUCKY LUNATIC ASYLUM, Anchorage, Ky | Aug., 1883, | 6 | 450 |
| THE VANDERBILT UNIVERSITY, Nashville, Tenn | 3 orders, 1880-1888, | 4 | 284 |
| UNIVERSITY OF NOTRE DAME, South Bend, Ind | Sept., 1885, | 1 | 40 |
| INDIANA SOLDIERS' & SAILORS' ORPHANS' HOME, Knightstown, Ind | Sept., 1887, | 2 | 240 |
| NORTHERN INDIANA HOSPITAL FOR INSANE, Logansport, Ind | July, 1885, | 4 | 400 |
| EASTERN INDIANA HOSPITAL FOR INSANE, Richmond, Ind. | July, 1885, | 4 | 400 |
| SOUTHERN INDIANA HOSPITAL FOR INSANE, Evansville, Ind | July, 1885, | 4 | 400 |
| NORTHERN HOSPITAL FOR INSANE, Elgin, Ill | Sept, 1885, | 1 | 75 |
| GAFF BUILDING, Chicago, Ill | Aug., 1881, | 1 | 104 |
| CHICAGO, BURLINGTON & QUINCY R. R., Chicago, Ill | Aug., 1887, | 1 | 136 |
| CITY OF SANDWICH, Sandwich, Ill | Aug., 1888, | 1 | 61 |
| NEW YORK LIFE INSURANCE COMPANY, St. Paul, Minn | Aug., 1888, | 2 | 312 |
| do do Kansas City, Mo | Sept., 1888, | 4 | 488 |
| do do Omaha, Neb | Sept., 1888, | 4 | 488 |
| do do Montreal, Canada | Sept., 1888, | 3 | 225 |

## STAZIONE CENTRALE D'ILLUMINAZIONE ELETTRICA.

A MILANO (SANTA RADEGONDA)




Babcock & Wilcox Boilers at the Societa Generale Italiana di Elettricita, Sistima Edison, Milan, Italy, 9 orders, from August 1882 to May, 1888. Total, 2082.

| | | Boilers. | H. P. |
|---|---|---|---|
| **UNIVERSITY OF CALIFORNIA**, Berkeley, Cal | April, 1885, | 1 | 15 |
| PACIFIC POWER COMPANY, San Francisco, Cal | May, 1885, | 2 | 208 |
| PUBLIC BA THS, City of Mexico, Mex | Feb., 1884, | 1 | 15 |
| COMPAÑIA DE ALMACENES DE DEPOSITO DE LA HABANA, Cuba | Sept., 1884, | 1 | 104 |
| GREENOCK PRISON, Greenock, Scotland | Sept., 1885, | 2 | 20 |
| CALTON PRISON, Edinburgh, Scotland | 2 orders, 1885-1886, | 3 | 124 |
| DR UMSHENGH BATHS, Edinburgh, Scotland | 3 do 1884-1885, | 2 | 28 |
| ALEXANDER SMITH, Town House, Aberdeen, Scotland | Feb., 1888, | 1 | 20 |
| PUTNEY SWIMMING BATHS, London, England | Oct., 1885, | 1 | 20 |
| A. D. DUNN, Laundry, London, England | May, 1885, | 1 | 84 |
| LONDON & TILBURY LAUNDRY COMPANY, Tilbury, England | Mar., 1886, | 2 | 216 |
| COLLEGE OF GRENOBLE, Grenoble, France | May, 1886, | 3 | 120 |
| NATIONAL LIBERAL CLUB, London, England | Aug., 1886, | 2 | 194 |
| JAMES LESLIE WONKLYN, Mont Dore Hotel, Bournemouth, Eng | May, 1888, | 1 | 65 |

## ELECTRIC LIGHTING, Etc.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| WALTHAM GAS LIGHT COMPANY, Electric Plant, Waltham, Mass | Dec., 1886, | 1 | 156 |
| NEW HAVEN ELECTRIC COMPANY, New Haven, Conn | Nov., 1888, | 2 | 208 |
| ELECTRIC CLUB, New York, N. Y | June, 1887, | 1 | 74 |
| CONSOLIDATED ELECTRIC LIGHT COMPANY, New York | 2 orders, 1888, | 3 | 750 |
| HARLEM LIGHTING COMPANY, New York, N. Y | Sept., 1887, | 1 | 300 |
| EDISON ELECTRIC ILLUMINATING COMPANY, New York | 3 orders, 1881-1887, | 14 | 2620 |
| do do Lawrence, Mass | 3 do 1882-1884, | 3 | 286 |
| do do Brockton, Mass | June, 1883, | 2 | 146 |
| do do Fall River, Mass | Oct., 1883, | 2 | 146 |
| do do Newburgh, N. Y | Nov., 1883, | 2 | 146 |
| do do Paterson, N. J | 2 orders, May and Oct., 1888, | 2 | 490 |
| do do Sunbury, Pa | May, 1883, | 1 | 51 |
| do do Shamokin, Pa | June, 1883, | 2 | 146 |
| do do Hazleton, Pa | Nov., 1883, | 1 | 92 |
| do do Bellefonte, Pa | 2 orders, 1883-1885, | 2 | 184 |
| do do Mt. Carmel, Pa | Nov., 1883, | 1 | 51 |
| do do Tiffin, Ohio | Nov., 1883, | 1 | 92 |
| do do Middletown, Ohio | 2 orders, 1883-1884, | 2 | 143 |
| do do Piqua, Ohio | Mar., 1884, | 1 | 92 |
| do do Circleville, Ohio | April, 1884, | 1 | 92 |
| do do New Orleans, La | June, 1888, | 2 | 312 |
| EDISON ELECTRIC LIGHT COMPANY, Paris, France | June, 1881, | 1 | 150 |
| do do London, Eng | 2 orders, 1881-1882, | 2 | 300 |
| EDISON LAMP COMPANY, Newark, N. J | 2 do 1881-1886, | 3 | 281 |
| THOS. A. EDISON, Fort Myer, Fla | Nov., 1885, | 1 | 45 |
| do Orange, N. J | Aug., 1887, | 3 | 219 |
| EDISON ELECTRIC LIGHT & POWER COMPANY, Kansas City, Mo | 2 orders, 1886-1888, | 8 | 1476 |
| EDISON COMPANY, FOR ISOLATED LIGHTING, Washington, D. C | April, 1884, | 2 | 164 |
| do do *N. Y. Herald*, N. Y. City | Nov., 1881, | 1 | 150 |
| WESTERN EDISON ELECTRIC LIGHT COMPANY, Chicago, Ill | July, 1882, | 1 | 40 |
| WESTERN ELECTRIC COMPANY, Chicago, Ill | Aug., 1888, | 1 | 208 |
| do do New York | Aug., 1888, | 3 | 448 |
| UNITED STATES ELECTRIC LIGHT COMPANY, New York | 2 orders, 1880, | 3 | 233 |
| do do Philadelphia, Pa | Mar., 1885, | 1 | 208 |
| do do Weston Factory, Newark, N. J | 4 orders, 1880-1887, | 5 | 389 |
| BRUSH ELECTRIC LIGHT COMPANY, Philadelphia, Pa | July, 1881, | 4 | 300 |
| BRUSH-SWAN ELECTRIC LIGHT COMPANY, Auburn, N. Y | Sept., 1885, | 1 | 60 |
| EXCELSIOR ELECTRIC COMPANY, Brooklyn, N. Y | Sept., 1888, | 1 | 50 |
| WESTINGHOUSE ILLUMINATING COMPANY, Schenectady, N. Y | Oct., 1887, | 2 | 292 |
| WESTINGHOUSE ELECTRIC COMPANY, Pittsburg, Pa | Nov., 1888, | 2 | 328 |
| ALLEGHENY COUNTY ELECTRIC LIGHT COMPANY, Pittsburg, Pa | 2 orders, Jan. and Dec., 1888, | 6 | 1325 |
| EAST END ELECTRIC LIGHT COMPANY, Pittsburgh, Pa | Dec., 1888, | 4 | 960 |
| UNITED STATES CAPITOL, HOUSE OF REPRESENTATIVES, Washington, D. C | 1887, | 1 | 82 |
| UNITED STATES INTERIOR DEPARTMENT (Patent Office), Washington, D. C | July, 1888, | 2 | 122 |
| UNITED STATES CAPITOL, SENATE WING, Washington, D. C | March, 1887, | 2 | 312 |
| BUCYRUS ELECTRIC LIGHT COMPANY, Bucyrus, Ohio | June, 1887, | 1 | 85 |
| ST. JOSEPH ELECTRIC LIGHT COMPANY, St. Joseph, Mo | 2 orders, 1883-1884, | 2 | 102 |
| KANSAS CITY ELECTRIC LIGHT COMPANY, Kansas City, Kansas | Oct., 1888, | 3 | 246 |
| MISSOURI ELECTRIC LIGHT AND POWER COMPANY, Kansas City, Mo | Jan., 1889, | 4 | 832 |
| A. HAYWARD, San Mateo, Cal | July, 1887, | 1 | 51 |
| ANGLO-AMERICAN BRUSH ELECTRIC LIGHT CO., LIMITED, Edinburgh, Scotland | Jan., 1887, | 1 | 25 |
| do do for Royalty Theatre, Edinburgh, Scotland | Dec., 1887, | 1 | 25 |
| do do Bosworth, Scotland | Aug., 1887, | 1 | 20 |
| do do London, Eng | 3 orders, 1888, | 3 | 176 |
| LONDON ELECTRIC SUPPLY CORPORATION, LIMITED, London, England | 4 do 1888, | 25 | 6093 |
| SIR COUTTS, LINDSAY & CO., Grosvenor Gallery, London, Eng | Oct., 1886, | 4 | 956 |
| CARDOGAN ELECTRIC LIGHT COMPANY, London, England | Oct., 1887, | 2 | 208 |
| EDISON-SWAN ELECTRIC LIGHT COMPANY, London, Eng | Jan., 1888, | 3 | 468 |
| S. Z. FERRANTI, Electrician, London, England | Feb., 1888, | 1 | 85 |
| LAING, WHARTON & DOWN, Electrical Engineers, London, England | 2 orders, 1885-1888, | 2 | 50 |
| THE HOUSE-TO-HOUSE ELECTRIC LIGHT SUPPLY CO., Kensington, London, England | May, 1888, | 3 | 468 |
| THE SCHMIDT-DOUGLASS ELECTRIC LIGHT CO. LIMITED, Huskegate, Bradford, Eng | 2 orders, 1887, | 2 | 235 |
| RESIDENCE OF MR. BRYANT, Dorking, England | Sept., 1885, | 2 | 25 |

| | | Boilers. | H. P. |
|---|---|---|---|
| RESIDENCE OF LORD ROTHSCHILD, Tring Park, Herts, Eng | June, 1887, | 1 | 60 |
| THE CHATHAM, ROCHESTER & DISTRICT ELECTRIC LIGHTING CO., Rochester, Eng. | Jan., 1888, | 1 | 124 |
| R. & E. CROMPTON & CO., Chelmsford, England | Oct., 1888, | 1 | 165 |
| McWHIRTER, FERGUSON & CO., Edinburgh, Scotland | 2 orders, 1887-1888, | 2 | 91 |
| SOCIETÀ GENERALE ITALIANA D'ELETTRICITA SISTIMA EDISON, Milan, Italy | 9 do 1882-1888, | 16 | 2082 |
| do do do do Livorno, Italy | Sept., 1887, | 3 | 438 |
| SOCIETÀ ANGLO-ROMANA PER L'ILLUMINAZIONE, Rome, Italy | 2 orders, 1885-1887, | 9 | 1362 |
| SOCIETÀ GENERALE PER L'ILLUMINAZIONE, PALAZZO CHIGI, Rome, Italy | Nov., 1888, | 2 | 328 |
| SOCIETÀ PER L'ILLUMINAZIONE ELETTRICA, Palermo, Italy | Sept., 1887, | 2 | 164 |
| ROYAL ITALIAN NAVY ARSENAL, Spezia, Italy | May, 1888, | 3 | 186 |
| HOTEL DE LILLE ET D'ALBION, Paris, France | May, 1886, | 1 | 20 |
| BEAN & BERTRAND FAILLET, Paris, France | Oct., 1888, | 1 | 120 |
| E. LAMY P. RIEU & CO., Mende, France | June, 1887, | 2 | 122 |
| A. GILLIBERT & CO., Marseilles, France | Oct., 1887, | 2 | 220 |
| SOCIÉTÉ NANCIENNE D'ÉLECTRICITÉ, Nancy, France | 2 orders, 1887-1888, | 3 | 518 |
| IMPERIAL CONTINENTAL GAS ASS'N (VIENNA OPERA HOUSE), Vienna, Austria | 2 orders, 1887-1888, | 8 | 992 |
| ELECTRICITEITS MATTSCHAPPY, SYSTEM DE KHOTINSKY, Rotterdam, Holland | Oct., 1884, | 2 | 164 |
| do do do Berlin, Germany | 2 orders, 1887, | 3 | 135 |
| CAPT. DE KHOTINSKY, Berlin, Germany | June, 1887, | 2 | 80 |
| FRANCISCO DE LA VIESCA, Cadiz, Spain | 2 orders, 1886-1887, | 2 | 102 |
| ALFONSO FLAQUER, for ELECTRIC LIGHT STATION, Valencia, Spain | 2 orders, 1888, | 6 | 864 |
| SOCIEDAD MATRITEUSE DE ELECTRICIDAD, Madrid, Spain | Aug., 1888, | 3 | 186 |
| CAMELA G. LAGANA, Palermo, Sicily | 2 orders, 1886-1887, | 2 | 122 |
| ELECTRIC LIGHT & POWER COMPANY, Melbourne, Australia | Aug., 1888, | 6 | 1500 |

## GAS LIGHTING.

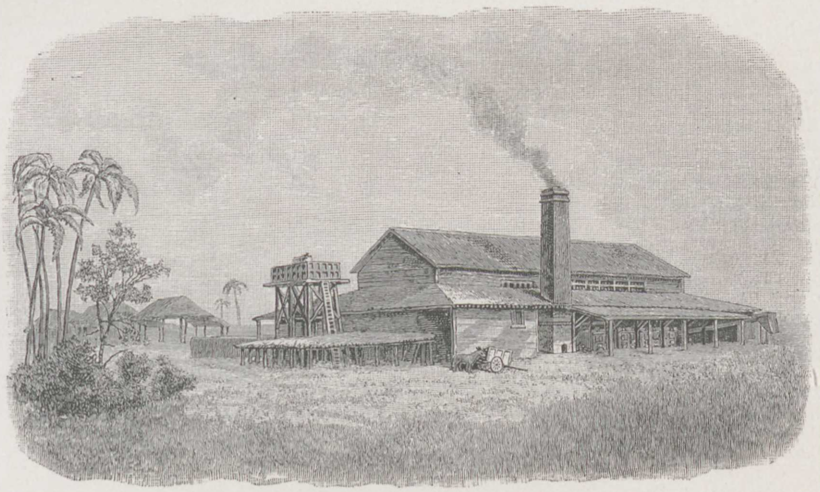
| | | Boilers. | H. P. |
|---|---|---|---|
| WALTHAM GAS LIGHT COMPANY, Waltham, Mass | Dec., 1886, | 1 | 156 |
| STANDARD GAS LIGHT COMPANY, New York, N. Y | Aug., 1887, | 2 | 500 |
| WILLIAMSBURGH GAS LIGHT COMPANY, Brooklyn, N. Y | Aug., 1884, | 1 | 164 |
| EAST RIVER GAS LIGHT COMPANY, Long Island City, N. Y | 2 orders, 1886-1888, | 2 | 102 |
| CINCINNATI GAS LIGHT AND COKE COMPANY, Cincinnati, Ohio, | Mar., 1883, | 2 | 184 |
| CITIZENS' GAS LIGHT AND HEATING COMPANY, Bloomington, Ill | April, 1884, | 1 | 51 |
| CORPORATION of GLASGOW, GLASGOW GAS TRUST, Glasgow, Scotland | Jan., 1888, | 2 | 220 |
| ABERDEEN CORPORATION, Aberdeen, Scotland | Jan., 1886, | 1 | 93 |
| EDINBURGH & LEITH GAS WORKS, Leith, Scotland | July, 1887, | 2 | 186 |
| DOWSON ECONOMIC GAS POWER COMPANY, London, S. W., England | 3 orders, 1888, | 6 | 114 |

## SUGAR REFINERIES.

| | | Boilers. | H. P. |
|---|---|---|---|
| BROOKLYN SUGAR REFINING COMPANY, Brooklyn, N. Y | 5 orders, 1876-1888, | 18 | 3952 |
| DECASTRO & DONNER SUGAR REFINING COMPANY, Brooklyn, N. Y | 8 do 1871-1888, | 21 | 3265 |
| HAVEMEYER SUGAR REFINING COMPANY, Brooklyn, N. Y | 5 do 1871-1883, | 14 | 2420 |
| HAVEMEYERS & ELDER SUGAR REFINING COMPANY, Brooklyn, N. Y | 2 do 1871-1872, | 8 | 600 |
| MATTHIESSEN & WIECHERS SUGAR REFINING CO., Jersey City, N. J | 8 do 1871-1886, | 21 | 5198 |
| HARRISON, FRAZIER & CO., Philadelphia, Pa | 9 do 1871-1886, | 32 | 6218 |
| E. C. KNIGHT & CO., Philadelphia, Pa | 3 do 1880-1887, | 8 | 1980 |
| PENNSYLVANIA SUGAR REFINING COMPANY, Philadelphia, Pa | Oct., 1881, | 2 | 250 |
| GROCERS' SUGAR HOUSE, Philadelphia, Pa | Oct., 1881, | 2 | 250 |
| CLAUS SPRECKELS SUGAR REFINERY, Philadelphia, Pa | Sept., 1888, | 30 | 7500 |
| BOSTON SUGAR REFINERY, East Boston, Mass., | 2 orders, 1880-1881, | 5 | 1250 |
| BAY STATE SUGAR REFINERY, Boston, Mass | 2 do 1880-1887, | 5 | 798 |
| STANDARD SUGAR REFINERY, Boston, Mass | Nov., 1880, | 2 | 500 |
| FOREST CITY SUGAR REFINING COMPANY, Portland, Me | 2 orders, 1881-1887, | 5 | 700 |
| AMERICAN GLUCOSE COMPANY, Buffalo, N. Y., Works A | 4 do 1879-1882, | 13 | 3050 |
| do Peoria, Ill., Works P | 2 do 1880-1888, | 8 | 1960 |
| do Leavenworth, Kan., Works L | Sept., 1882, | 4 | 500 |
| CHICAGO SUGAR REFINING COMPANY, Chicago, Ill | 4 orders, 1880-1888, | 20 | 4206 |
| ROCKFORD GRAPE SUGAR COMPANY, Rockford, Ill | May, 1882, | 2 | 300 |
| BELCHER SUGAR REFINING COMPANY, St. Louis, Mo | 2 orders, 1872-1881, | 9 | 1925 |
| KANSAS CITY GRAPE SUGAR COMPANY, Kansas City, Mo | May, 1883, | 2 | 292 |
| ST. JOSEPH SUGAR REFINERY, St. Joseph, Mo | 2 orders, 1880-1881, | 4 | 535 |
| FIRMINICH MANUFACTURING COMPANY, Marshalltown, Iowa | 2 do 1880-1882, | 8 | 1250 |
| MICHIGAN GRAPE SUGAR COMPANY, Detroit, Mich | May, 1880, | 4 | 1000 |
| FLORIDA SUGAR REFINING COMPANY, St. Cloud, Fla | 2 orders, 1887-1888, | 5 | 738 |
| LOUISIANA SUGAR REFINING COMPANY, New Orleans, La | 4 do 1883-1888, | 6 | 1440 |
| PLANTERS' SUGAR REFINERY, New Orleans, La | 2 do 1882-1888, | 3 | 532 |
| NOVA SCOTIA SUGAR REFINERY, Halifax, N. S | 3 do 1880-1884, | 8 | 808 |
| MONCTON SUGAR REFINING COMPANY, Moncton, N. B | 2 do 1880-1885, | 3 | 456 |
| REFINERIA DE AZUCAR DE CARDENAS, Cardenas, Cuba | 6 do 1883-1886, | 17 | 2177 |
| SAY ET CIE, Paris, France | Nov., 1886, | 1 | 130 |
| BERNARD NEVEUX, Santes, France | May, 1887, | 1 | 240 |
| SALA PON Y CIA., Barcelona, Spain | 2 orders, 1887-1888, | 2 | 208 |
| LA REFINERIA DE BARCELONA, Barcelona, Spain | Feb., 1888, | 2 | 208 |
| PLANAS ESCUBOS HERMANOS, Barcelona, Spain | July, 1888, | 1 | 75 |
| SOCIETÀ ANONIMA RAFFINERIA DI ZUCCHERI, Ancona, Italy | 2 orders, 1886-1888, | 6 | 732 |
| LEE YEUN SUGAR REFINING COMPANY, Hong Kong, China | Sept., 1883, | 1 | 104 |
| RECIPROCITY SUGAR COMPANY, Hana, Maui, Hawaiian Islands | Nov., 1883, | 1 | 122 |
| PUGA SUGAR REFINERY, Tepic, Puebla, Mexico | Nov., 1883, | 1 | 104 |

# SUGAR PLANTATIONS.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| NORTH BEND PLANTATION, near Centreville, La. | 2 orders, Mar. and Nov., 1879, | 4 | 400 |
| D. F. KENNER, Plantation, Hermitage, La. | May, 1881, | 2 | 258 |
| FOOS & BARNETT, Plantation, Centreville, La. | July, 1881, | 1 | 120 |
| R. H. YALE, Ascension Parish, La. | April, 1883, | 2 | 244 |
| WM. H. BALLARD, Chatham Plantation, Ascension Parish, La. | Mar., 1883, | 2 | 208 |
| JNO. CROSSLEY & SONS, Ld., Southwood Plantation, Ascension Parish, La. | 4 orders, 1883—1886, | 8 | 1510 |
| JNO. CROSSLEY & SONS, Ld., Mt. Houmas Plantation, Ascension Parish, La. | 2 do 1883—1886, | | |
| J. H. PUTNAM, Rose Hill Plantation, Abbeville, La. | April, 1883, | 1 | 122 |
| SCHMIDT & ZIEGLER, Willswood Plantation, New Orleans, La. | June, 1886, | 2 | 328 |
| WELHAM ESTATE, St. James Parish, La. | 2 orders, 1886-1888, | 3 | 636 |
| Yngenio "TOLEDO Y PILAR," Havana, Cuba | Sept., 1888, | 2 | 300 |
| Yngenio "UNION," Cuevitas, Cuba | 4 orders, 1879-1886, | 8 | 1100 |
| Yngenio "SAN RAMON," Manzanillo, Cuba | 2 do 1882-1883, | 3 | 312 |
| Yngenio "CENTRAL YSABEL," Media Luna, Manzanillo, Cuba | April, 1886, | 8 | 976 |
| Yngenio "SANTA ROSA," Guantanamo, Cuba | July, 1881, | 1 | 150 |
| Yngenio "SAN ANTONIO," do do | 2 orders, 1881-1883, | 3 | 442 |
| Yngenio "SOLEDAD," do do | 3 do 1880-1888, | 4 | 281 |
| Yngenio "LOS CAÑOS," do do | 2 do 1883-1884, | 4 | 305 |
| Yngenio "SAN JOSÉ," do do | May, 1881, | 4 | 300 |
| Yngenio "SAN VINCENTE," do do | Aug., 1885, | 2 | 164 |
| Yngenio "SANTA MARIA," do do | 3 orders, 1882-1885, | 3 | 221 |
| Yngenio "SANTA FÉ," do do | July, 1883, | 1 | 146 |
| Yngenio "BELLEZA," Santiago, Cuba | May, 1881, | 2 | 150 |
| Yngenio "SAN SEBASTIAN," Santiago, Cuba | 2 orders, 1884-1886, | 2 | 164 |



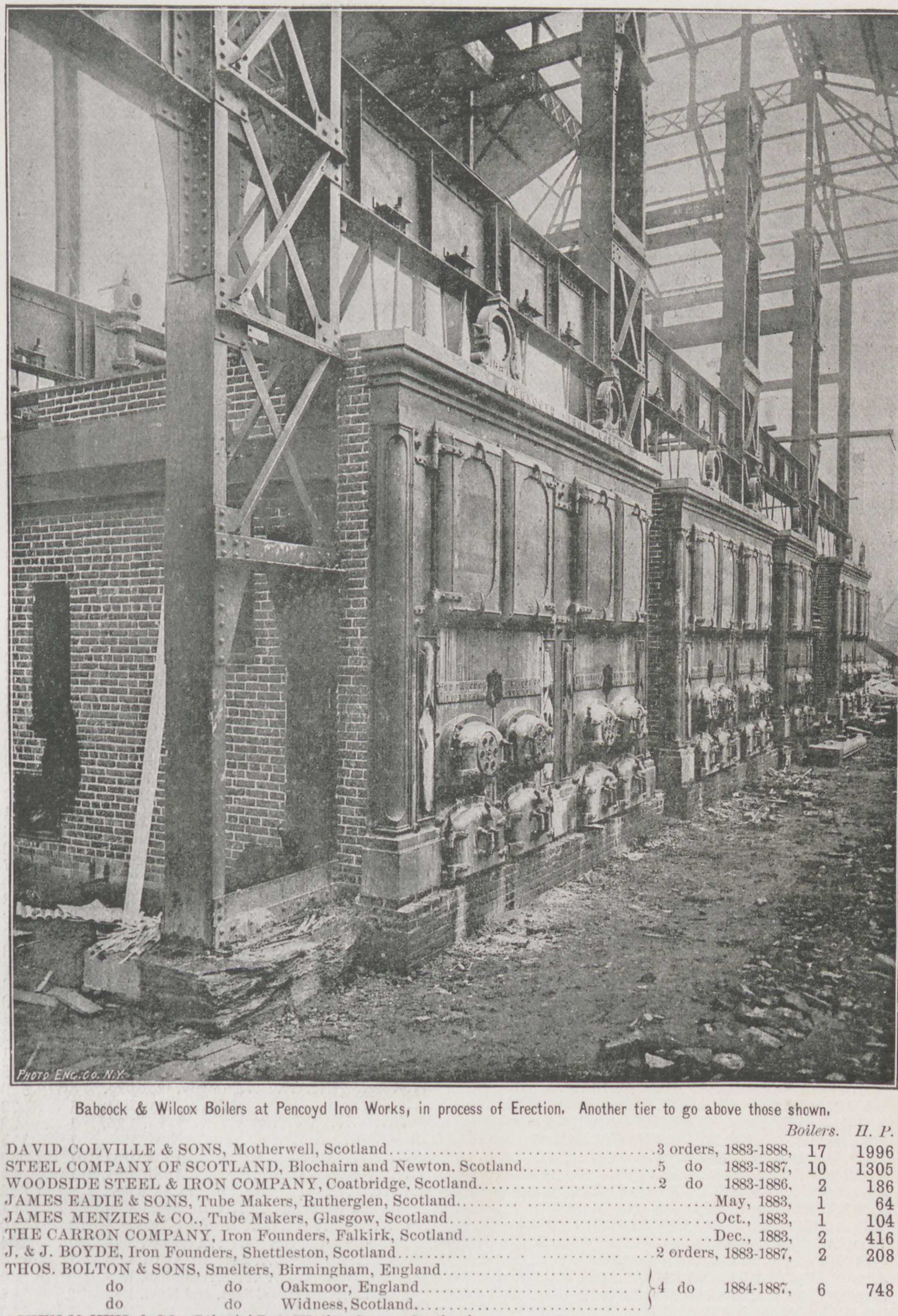
Yngenio Central Ysabel, Media Luna, Manzanillo, Cuba.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| Yngenio "HORMIGUERO," Palmira, Cuba | 2 orders, 1881-1882, | 4 | 300 |
| Yngenio "CONSTANCIA," Cienfuegos, Cuba | 6 do 1881-1887, | 17 | 2264 |
| Yngenio "LEQUEITIO," do | 3 do 1887-1888, | 5 | 649 |
| Yngenio "SAN LINO," do | Nov., 1887, | 2 | 292 |
| Yngenio "SOLEDAD," do | June, 1888, | 1 | 156 |
| Yngenio "CIENEGUITA," Abreus, Cuba | 3 orders, 1882-1888, | 4 | 596 |
| Yngenio "CENTRAL REDENCION," Nuevitas, Cuba | Jan., 1883, | 2 | 146 |
| Yngenio "LA CARIDAD," do | June, 1883, | 2 | 240 |
| Yngenio "EL CONGRESO," do | 7 orders, 1883-1885, | 7 | 1228 |
| Yngenio "SENADO," do | 3 do 1883-1886, | 4 | 790 |
| Yngenio "GRATITÛD," Manacas, Cuba | Aug., 1883, | 2 | 208 |
| Yngenio "FORTUNA," Alquizar, Cuba | July, 1883, | 6 | 624 |
| Yngenio "SAN LUCIANO," Macagua, Cuba | July, 1884, | 2 | 208 |
| Yngenio "SAN CLAUDIO," Cabañas, Cuba | 2 orders, 1884-1885, | 5 | 615 |
| Yngenio "SANTA CATALINA," Corral Falso, Cuba | 4 do 1885-1888, | 7 | 820 |
| Yngenio "SANTA FILOMENA,," Corral Falso, Cuba | June, 1885, | 4 | 416 |
| Yngenio "SANTA RITA," Baro, Cuba | Jan., 1886, | 2 | 208 |
| Yngenio "SAN JOAQUIN," Pedroso, Cuba | Aug., 1884, | 2 | 208 |
| Yngenio "NUESTRA SEÑORA DEL CARMEN," Matanzas, Cuba | Jan., 1886, | 1 | 146 |
| Yngenio "JESUS MARIA EN SANTA ANA," Matanzas, Cuba | Oct., 1888, | 1 | 150 |
| Yngenio "TERESA," Cruces, Cuba | 2 orders, 1884-1885, | 4 | 416 |
| Yngenio "EMILIA," Güines, Cuba | 2 do 1884-1885, | 3 | 386 |
| Yngenio "SOCORRO," Corralillo, Cuba | May, 1885, | 2 | 292 |
| Yngenio "SANTA ISABEL," Sagua, Cuba | Sept., 1885, | 1 | 104 |
| Yngenio "ASUNCION," Mariel, Cuba | July, 1885, | 2 | 203 |
| Yngenio "DOS AMIGOS," Campechuela, Cuba | 2 orders, 1884-1886, | 4 | 416 |

| | | Boilers. | H. P. |
|---|---|---|---|
| Yngenio "CAÑAMABO," Trinidad, Cuba | Sept., 1885, | 2 | 292 |
| Yngenio "SANTA GERTRUDES," Banaguises, Cuba | 2 orders, 1885-1887, | 3 | 438 |
| Yngenio "SAN AUGUSTIN," Quibian, Cuba | Aug., 1886, | 1 | 140 |
| Yngenio "MI ROSA," Quibian, Cuba | Oct., 1886, | 2 | 300 |
| Yngenio "SAN FERNANDO," St. Spiritus, Cuba | Oct., 1886, | 1 | 104 |
| Yngenio "SANTA TERESA," Ceiba Hueca, W. I | Jan., 1886, | 1 | 208 |
| Yngenio "ANGELINA," San Domingo, W. I | Aug., 1879, | 1 | 75 |
| Hacienda "FORTUNA," Porto Rico | Nov., 1883, | 1 | 104 |
| Hacienda "FLORIDA YANCO," Porto Rico | Jan., 1884, | 1 | 104 |
| Hacienda "REPARADA," Porto Rico | Feb., 1885, | 1 | 104 |
| Hacienda "LOS CAÑOS," Porto Rico | Sept., 1886, | 1 | 104 |
| Hacienda "GUARACHA," Irapuato, Mexico | Aug., 1884, | 1 | 122 |
| Hacienda "SAN MARCOS," Jalisco, Mexico | 2 orders, 1884-1885, | 4 | 244 |
| GARCIA ICAZBALCETA HERMANOS, City of Mexico | 2 orders, Nov., 1887, | 2 | 184 |
| Señor SOLERO ESCARZA, Cienfuegos, Cuba | July, 1888, | 3 | 450 |
| Yngenio "VICTORIA EN GRECIA," Costa Rica | March, 1886, | 1 | 51 |
| HAWAIIAN AGRICULTURAL COMPANY, Pahala, Sandwich Islands | 2 orders, 1886, | 3 | 490 |

## IRON WORKS.

| | | Boilers. | H. P. |
|---|---|---|---|
| TROY IRON & STEEL COMPANY, Troy, N. Y | 3 orders, 1885-1888, | 12 | 1786 |
| SWEET'S MANUFACTURING CO., Syracuse, N. Y | 4 orders, 1881-1883, | 4 | 344 |
| PHŒNIX HORSE SHOE COMPANY, Poughkeepsie, N. Y | June, 1888, | 1 | 146 |
| GLOBE NAIL COMPANY, Boston, Mass | May, 1880, | 2 | 200 |
| W. AMES & CO., Jersey City, N. J | Nov., 1884, | 1 | 240 |
| TRENTON IRON COMPANY, Trenton, N. J | 4 orders, 1880-1882, | 6 | 420 |
| NEW JERSEY STEEL & IRON COMPANY, Trenton, N. J | Dec., 1885, | 1 | 208 |
| AMERICAN SHEET IRON WORKS, Phillipsburg, N. J | Mar., 1882, | 1 | 73 |
| DELAWARE ROLLING MILL, Phillipsburg, N. J | June, 1882, | 1 | 82 |
| McDANIEL & HARVEY COMPANY, Sheet Irons, Philadelphia, Pa | June, 1882, | 1 | 100 |
| HUGHES & PATTERSON, Philadelphia, Pa | Jan., 1886, | 2 | 208 |
| GORDON, STROBEL & LAUREAU, L'd, Philadephia, Pa | 8 orders, 1886-1888, | 35 | 4390 |
| MIDVALE STEEL COMPANY, Nicetown, Philadelphia, Pa | Dec., 1887, | 2 | 272 |
| MARSHALL BROTHERS & CO., Newport, Pa, | June, 1888, | 2 | 272 |
| CATASAUQUA MANUFACTURING CO., Catasauqua, Pa | 2 orders, 1881-1883, | 2 | 202 |
| PENCOYD IRON WORKS, Pencoyd, Pa | 4 do 1881-1887, | 12 | 1824 |
| CHICKIES IRON COMPANY, Chickies, Pa | 2 do 1887-1888, | 4 | 512 |
| PENNSYLVANIA STEEL COMPANY, Steelton, Pa | 2 do 1880-1884, | 3 | 540 |
| do do Sparrows Point, Md | June, 1887, | 16 | 3840 |
| LONGMEAD IRON WORKS, Conshohocken, Pa | 2 orders, 1882-1887, | 4 | 241 |
| ROBESONIA IRON COMPANY (L'd.), Robesonia, Pa | Nov., 1885, | 2 | 480 |
| AMERICAN TUBE & IRON COMPANY, Middletown, Pa | Jan., 1888, | 1 | 51 |
| IOWA BARB WIRE COMPANY, Allentown, Pa | Sept., 1886, | 4 | 624 |
| COLUMBIA ROLLING MILL COMPANY, Vesta Furnace, Watts, Pa | Feb., 1887, | 1 | 136 |
| POTTSVILLE IRON & STEEL COMPANY, Pottsville, Pa | 2 orders, 1884-1885, | 3 | 350 |
| MAHONING ROLLING MILL COMPANY, Danville, Pa | 2 do 1887, | 2 | 250 |
| DANVILLE STOVE & MANUFACTURING CO., Danville, Pa | Oct., 1887, | 1 | 104 |
| McCORMICK & CO., Paxton Furnaces, Harrisburg, Pa | Oct., 1884, | 2 | 416 |
| LOCHIEL ROLLING MILL COMPANY, Harrisburg, Pa | Oct., 1884, | 2 | 416 |
| BIRD COLEMAN FURNACES, Cornwall, Pa | 3 orders, 1886-1888, | 8 | 1260 |
| LEBANON FURNACES, Lebanon, Pa | 2 do 1885-1886, | 4 | 970 |
| J. & R. MEILY, Lebanon, Pa | Feb., 1887, | 2 | 208 |
| LICKDALE IRON COMPANY, Lickdale, Pa | Feb., 1887, | 3 | 450 |
| CAMBRIA IRON COMPANY., Johnstown, Pa | 3 orders, 1883-1885, | 6 | 896 |
| PITTSBURGH STEEL CASTING COMPANY, Pittsburgh, Pa | Nov., 1883, | 2 | 416 |
| LUCY FURNACES, Pittsburgh, Pa | Nov., 1883, | 4 | 832 |
| OLIVER & ROBERTS WIRE COMPANY (L'd.), Pittsburgh, Pa | 4 orders, 1882-1888, | 10 | 2080 |
| CARNEGIE BROTHERS & CO. (L'd), Pittsburgh, Pa | April, 1884, | 2 | 416 |
| THE HARTMAN STEEL COMPANY (L'd) Beaver Falls, Pa | 2 orders, 1882-1883, | 4 | 544 |
| LATROBE STEEL WORKS, Latrobe, Pa | 2 do 1888-1889, | 6 | 1248 |
| NATIONAL TUBE WORKS COMPANY, McKeesport, Pa | Mar., 1887, | 1 | 156 |
| McCULLOUGH IRON COMPANY, Wilmington, Del | 4 orders, 1874-1882, | 14 | 700 |
| do North East, Md | 4 do 1880-1883, | 4 | 308 |
| do Carbon Station, Md | April, 1884, | 1 | 45 |
| OLD DOMINION IRON & NAIL WORKS COMPANY, Richmond, Va | 2 orders, 1886-1888, | 3 | 408 |
| D. S. COOK, Princess Furnace, Glen Wilton, Va | June, 1887, | 2 | 312 |
| TENNESSEE COAL, IRON & RAILROAD COMPANY, So. Pittsburgh, Tenn | May, 1887, | 4 | 624 |
| NASHVILLE IRON, STEEL & CHARCOAL COMPANY, W. Nashville, Tenn | Mar., 1887, | 4 | 480 |
| CHEROKEE IRON COMPANY, Cedartown, Ga | Feb., 1886, | 2 | 480 |
| WOODWARD IRON COMPANY, Woodward, Ala | 3 orders, 1884-1888, | 8 | 978 |
| ALABAMA & TENNESSEE COAL & IRON COMPANY, Sheffield, Ala | Feb., 1887, | 12 | 1872 |
| GADSDEN ALABAMA FURNACE COMPANY, Gadsden, Ala | Mar., 1887, | 4 | 624 |
| DECATUR LAND IMPROVEMENT & FURNACE COMPANY, Decatur, Ala | April, 1887, | 4 | 292 |
| SLOSS STEEL & IRON COMPANY, North Birmingham, Ala | Mar., 1887, | 8 | 1248 |
| SHELBY IRON COMPANY, Shelby, Ala | July, 1888, | 4 | 292 |
| COLUMBUS STEEL COMPANY, Columbus, Ohio | June, 1886, | 4 | 480 |
| JAS. E. THOMAS, Founder, Newark, Ohio | Aug., 1882, | 1 | 50 |
| UNION FOUNDRY & CAR WHEEL WORKS, Pullman, Ill | July, 1881, | 1 | 60 |
| FREEPORT MALLEABLE IRON COMPANY, Freeport, Ill | Sept., 1881, | 1 | 60 |
| ARROL BROTHERS, Glasgow, Scotland | April, 1883, | 2 | 146 |




Babcock & Wilcox Boilers at Pencoyd Iron Works, in process of Erection. Another tier to go above those shown.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| DAVID COLVILLE & SONS, Motherwell, Scotland | 3 orders, 1883-1888, | 17 | 1996 |
| STEEL COMPANY OF SCOTLAND, Blochairn and Newton, Scotland | 5 do 1883-1887, | 10 | 1305 |
| WOODSIDE STEEL & IRON COMPANY, Coatbridge, Scotland | 2 do 1883-1886, | 2 | 186 |
| JAMES EADIE & SONS, Tube Makers, Rutherglen, Scotland | May, 1883, | 1 | 64 |
| JAMES MENZIES & CO., Tube Makers, Glasgow, Scotland | Oct., 1883, | 1 | 104 |
| THE CARRON COMPANY, Iron Founders, Falkirk, Scotland | Dec., 1883, | 2 | 416 |
| J. & J. BOYDE, Iron Founders, Shettleston, Scotland | 2 orders, 1883-1887, | 2 | 208 |
| THOS. BOLTON & SONS, Smelters, Birmingham, England<br>do do Oakmoor, England<br>do do Widness, Scotland | 4 do 1884-1887, | 6 | 748 |
| AIKEN McNEIL & CO., Colonial Iron Works, Govan, Scotland | Sept., 1888, | 1 | 110 |
| THE SUMMERLEE & MOSSEND IRON & STEEL CO., Mossend, Scotland | Sept., 1888, | 5 | 700 |
| WM. BEARDMORE & CO., Parkhead, Scotland | Oct., 1888, | 1 | 140 |
| BRADLEY & CRAVEN, Founders, Wakefield, England | Dec. 1887, | 1 | 108 |
| SOCIÉTÉ INDUSTRIALE NAPOLETANA, Naples, Italy | July, 1885, | 1 | 140 |
| SOCIÉTÉ INDUSTRIELLE ET COMMERCIALE DE MÉTAUX, Livorno, Italy | July, 1886, | 7 | 644 |

## BRASS WORKS, Etc.

| | | Boilers. | H. P. |
|---|---|---|---|
| THE SETH THOMAS CLOCK COMPANY, Thomaston, Conn | June, 1880, | 1 | 125 |
| THE SCOVILLE MANUFACTURING CO., Waterbury, Conn | 2 orders, 1879-1882, | 4 | 500 |
| BENEDICT & BURNHAM MANUFACTURING CO., Waterbury, Conn | 2 do 1882-1886, | 2 | 406 |
| WALLACE & SONS, Ansonia, Conn | 2 orders, 1878-1881, | 6 | 520 |
| ASHCROFT MANUFACTURING CO., Bridgeport, Conn | Dec., 1885, | 1 | 73 |
| CONSOLIDATED SAFETY VALVE COMPANY, Bridgeport, Conn | Dec., 1885, | 1 | 30 |
| HOOLE MANUFACTURING CO., Brass Checks, etc., New York | Feb., 1882, | 1 | 50 |
| E. P. GLEASON MANUFACTURING CO., Gas Fixtures, New York | Jan., 1883, | 1 | 122 |
| ANSONIA CLOCK COMPANY, Brooklyn, N. Y | 2 orders, 1879-1884, | 4 | 414 |
| ROSS BROTHERS & WHISTLER, Wabash, Ind | Jan., 1883, | 1 | 61 |
| CHARLES BARWELL, Copper Tube Mill, Birmingham, Eng | June, 1887, | 1 | 85 |
| M. CLIN, Brassworks, Paris, France | May, 1885, | 2 | 102 |
| COPPER & BRASS WORKS MANUFACTURING CO., Koltschugine, near Moscow, Russia | Jan., 1885, | 3 | 219 |

## MACHINERY AND ENGINEERING.

| | | Boilers. | H. P. |
|---|---|---|---|
| DALZELL AXLE COMPANY, South Egremont, Mass | Mar., 1887, | 1 | 122 |
| NICHOLSON FILE WORKS, Providence, R. I | Aug., 1881, | 1 | 104 |
| E. JENCKES MANUFACTURING CO., Pawtucket, R. I | Mar., 1887, | 2 | 240 |
| PROVIDENCE STEAM & GAS PIPE CO., Providence, R. I | Sept., 1888, | 1 | 71 |
| C. B. COTTRELL & SONS, Printing Presses, Westerly, R. I | 2 orders, 1882-1888, | 2 | 177 |
| STANDARD MACHINERY COMPANY, Mystic River, Conn | Sept., 1881, | 1 | 60 |
| UNION METALLIC CARTRIDGE COMPANY, Bridgeport, Conn | Mar., 1884, | 3 | 276 |
| EXCELSIOR NEEDLE COMPANY, Torrington, Conn | June, 1886, | 1 | 61 |
| TURNER & SEYMOUR MANUFACTURING CO., Torrington, Conn | 2 orders, 1880-1881, | 2 | 100 |
| BROWN COTTON GIN COMPANY, New London, Conn | Oct., 1887, | 1 | 104 |
| T. SHRIVER & CO., Fine Castings and Copying Presses, New York | April, 1882, | 1 | 45 |
| LALANCE & GROSJEAN MANUFACTURING CO., Tinware, Whitestone, L. I., N. Y | Sept., 1882, | 1 | 73 |
| PORT CHESTER BOLT & NUT COMPANY, Port Chester, N. Y | July, 1882, | 1 | 50 |
| S. S. HEPWORTH & CO., Yonkers, N. Y | June, 1882, | 1 | 104 |
| WHEELER, MADDEN & CLEMSEN MANUFACTURING CO., Middletown, N. Y | May, 1883, | 2 | 244 |
| SCHENECTADY LOCOMOTIVE WORKS, Schenectady, N. Y | Feb., 1888, | 1 | 125 |
| E. C. STEARNS & CO., Hardware, Syracuse, N. Y | Mar., 1882, | 1 | 50 |
| FRANCIS AXE COMPANY, Buffalo, N. Y | 3 orders, 1882-1883, | 3 | 197 |
| EDISON MACHINE WORKS, Schenectady, N. Y | 4 orders, 1881-1888, | 6 | 700 |
| EDISON PHONOGRAPH WORKS, Orange, N. J. | May, 1888, | 2 | 146 |
| A. H. McNEAL, Pipe Foundry, Burlington, N. J. | Sept., 1884, | 1 | 104 |
| FAYETTE R. PLUMB, Cutlery, Philadelphia, Pa | April, 1881, | 2 | 184 |
| H. W. BUTTERWORTH & SONS, Philadelphia, Pa | June, 1881, | 1 | 100 |
| GEO. V. CRESSON, Shafting, Philadelphia, Pa | Feb., 1880, | 1 | 50 |
| W. H. & C. W. ALLEN, Hardware, Philadelphia, Pa | April, 1882, | 2 | 100 |
| GORDON, STROBEL & LAUREAU, L'd., Philadelphia, Pa | Jan., 1887, | 1 | 45 |
| READING BOLT & NUT WORKS, Reading, Pa | Sept., 1886, | 1 | 82 |
| WESTINGHOUSE AIR BRAKE COMPANY, Pittsburgh, Pa | 3 orders, 1883-1888, | 6 | 664 |
| BLACK & GERMER, Stoves, Erie, Pa | Oct., 1883, | 1 | 92 |
| HARLAN & HOLLINGSWORTH COMPANY, Iron Ships, Wilmington, Del | Dec., 1871, | 2 | 100 |
| THE JACKSON & SHARP COMPANY, Wilmington, Del | 5 orders, 1881-1888, | 8 | 717 |
| THE J. MORTON POOLE COMPANY, Wilmington, Del | Oct., 1873, | 2 | 100 |
| UNITED STATES NAVY YARD, Washington, D. C | 2 do 1885-1888, | 7 | 1248 |
| do Norfolk, Va | April, 1887, | 3 | 183 |
| J. A. FAY & CO., Cincinnati, O | Oct., 1881, | 2 | 150 |
| CINCINNATI CORRUGATING COMPANY, Cincinnati, O | Feb., 1884, | 1 | 73 |
| GORDON & MAXWELL COMPANY, Pumps, Hamilton, Ohio | Feb., 1887, | 1 | 45 |
| NILES TOOL WORKS, Hamilton, Ohio | Aug., 1888, | 2 | 146 |
| BLACK & CLAWSON, Hamilton, Ohio | Aug., 1888, | 1 | 95 |
| FLINT & WALLING MANUFACTURING CO., Wind Engines, Kendallville, Ind | Feb., 1884, | 1 | 164 |
| M. C. HENLEY, Skates, Richmond, Ind | April, 1884, | 1 | 73 |
| SOUTH BEND PUMP COMPANY, South Bend., Ind | Oct., 1886, | 1 | 61 |
| FIELDHOUSE & DUTCHER MFG. CO., Chicago, Ill | Feb., 1882, | 1 | 75 |
| M. LASSIG, Bridge Builder, Chicago, Ill | 3 orders, 1883-1887, | 4 | 530 |
| MASON & DAVIS COMPANY, Bridge Builders, Chicago, Ill | May, 1881, | 1 | 73 |
| KANSAS CITY BRIDGE & IRON COMPANY, Kansas City, Mo | April, 1886, | 1 | 92 |
| AMERICAN BRAKE COMPANY (Westinghouse Lessee), St. Louis, Mo | Nov., 1888, | 1 | 125 |
| TATUM & BOWEN, San Francisco, Cal | April, 1882, | 1 | 60 |
| HOLBROOK, MERRILL & STETSON, San Francisco, Cal | April, 1886, | 1 | 25 |
| JUDSON MANUFACTURING COMPANY, San Francisco, Cal | 3 orders, 1883-1887, | 3 | 352 |
| KENNEDY'S PATENTED WATER METER CO., Limited, Kilmarnock, Scotland | Mar., 1883, | 1 | 51 |
| THE GLENFIELD COMPANY LIMITED, Kilmarnock, Scotland | 2 orders, 1883-1888, | 2 | 260 |
| THOMAS SHANKS & CO., Johnstone, Scotland | Aug., 1883, | 1 | 104 |
| JAMES KEITH, Arbroath, Scotland | Dec., 1885, | 1 | 20 |
| JAMES SIMPSON & CO. LIMITED, Pimlico, London, England | 2 orders, 1888, | 5 | 538 |
| SHARP & KENT, Electrical Engineers, London, England | 2 orders, Sept. and Nov., 1888, | 3 | 164 |
| CHARLES McNEIL, JR., Maker of Manhole Doors, &c., Glasgow, Scotland | Oct., 1888, | 1 | 126 |
| MILLER & CO., Edinburgh, Scotland | 2 orders, 1885-1886, | 2 | 240 |
| GWYNNE & CO., Hydraulic Engineers (for So. Africa), London, England | Nov., 1888, | 1 | 23 |
| T. COULTHARD & CO., Spinning Machinery, Preston, England | April, 1887, | 2 | 280 |
| L. WHITAKER & SONS, Crane Railroad Mill, Haslingden, England | May, 1887, | 1 | 140 |
| GEO. RICHARD & CO., LIMITED, Broadheath, near Manchester, England | Oct., 1887, | 1 | 122 |

| | | Boilers. | H. P. |
|---|---|---|---|
| A. & F. PARKER & CO., LIMITED, Mfrs. of Forks, Spades, &c., Birmingham, England | June, 1888, | 1 | 140 |
| PLAYER BROTHERS, Birmingham, England | June, 1888, | 2 | 220 |
| CHAVANNE BRUN ET CIE, Chamond, France | Oct., 1888, | 2 | 248 |
| LOUIS FONTAINE, La Madelaine les Lille, France | 44 orders, 1883-1888, | 61 | 9064 |
| MERMIER ET CIE, Firearms, St. Étienne, France | Dec., 1886, | 1 | 120 |
| S. LAMBERT ET FILS, Tinware, Paris, France | Mar., 1887, | 1 | 69 |
| BAUER & SCHAURTE, Bolt & Nut Works, Neuss, Germany, | April, 1887, | 1 | 136 |
| BERLINER MACHINENBAU ACTIEN-GESELSCHAFT, Berlin, Germany | 3 orders, Mar. to Oct., 1888, | 3 | 312 |
| GEBRUEDER SULZER, Winterthur, Germany | Aug., 1888, | 1 | 140 |
| CALVART & CO., Gothenburg, Sweden | Sept., 1888, | 1 | 124 |
| LA ESPAÑA INDUSTRIAL, Barcelona, Spain | 2 orders, 1888, | 6 | 748 |
| GOVERNMENT MACHINE WORKS, Boyaca, U. S. C. | 2 do 1880, | 6 | 220 |

## SEWING MACHINES.

| | | Boilers. | H. P. |
|---|---|---|---|
| THE SINGER MANUFACTURING COMPANY, New York | 9 orders, 1871-1886, | 16 | 1677 |
| do do Elizabethport, N. J. | 9 do 1872-1887, | 20 | 2162 |
| do do South Bend, Ind. | 6 do 1871-1881, | 8 | 1110 |
| do do Cairo, Ill. | June, 1881, | 4 | 292 |
| do do Montreal, Canada | 2 orders, 1885-1887, | 3 | 217 |
| do do Glasgow, Scotland | 8 do 1882.1888, | 16 | 2106 |
| WHITE SEWING MACHINE COMPANY, Cleveland, Ohio | Dec., 1880, | 2 | 200 |
| MELONE SEWING MACHINE COMPANY, Chillicothe, Ohio | Feb., 1883, | 1 | 73 |
| WHITEHILL MANUFACTURING COMPANY, Milwaukee, Wis. | June, 1881, | 2 | 146 |

## AGRICULTURAL MACHINERY.

| | | Boilers. | H. P. |
|---|---|---|---|
| WALTER A. WOOD MOWING & REAPING MACHINE COMPANY, Hoosick Falls, N.Y. | 2 orders, 1882-1883, | 3 | 360 |
| THE WHITMAN & BARNES MANUFACTURING CO., Syracuse, N. Y. | May, 1883, | 3 | 408 |
| PITTS AGRICULTURAL WORKS, Buffalo, N. Y. | Oct., 1884, | 2 | 102 |
| SHEBLE & FISHER, Fork Mfrs., Philadelphia, Pa. | April, 1881. | 2 | 120 |
| WHITELEY, FASSLER & KELLEY COMPANY, Springfield, O. | Mar., 1881, | 4 | 400 |
| CHAMPION KNIFE & BAR COMPANY, Springfield, O. | Nov., 1880, | 2 | 300 |
| P. P. MAST & CO., Springfield, O. | May, 1880, | 1 | 85 |
| THE SPRINGFIELD ENGINE & THRESHER COMPANY, Springfield, O. | Sept., 1880, | 1 | 85 |
| WARDER, BUSHNELL & GLESSNER COMPANY, Springfield, O. | 3 orders, 1882-1887, | 6 | 650 |
| HOOSIER DRILL COMPANY, Richmond, Ind. | Mar., 1882, | 2 | 150 |
| ECONOMIST PLOW COMPANY, South Bend, Ind. | Dec., 1882, | 1 | 146 |
| SOUTH BEND IRON WORKS, Plows, So. Bend, Ind. | 2 orders, 1875-1888, | 4 | 600 |
| McCORMICK HARVESTING MACHINE COMPANY, Chicago, Ill. | Aug., 1884, | 4 | 480 |
| MADISON PLOW COMPANY, Madison, Wis. | Mar., 1882, | 2 | 208 |
| SOCIÉTÉ FRANÇAISE DE METÉRIEL AGRICOLE, Vierzon, France | June, 1888, | 1 | 63 |

## CABLE TOWAGE.

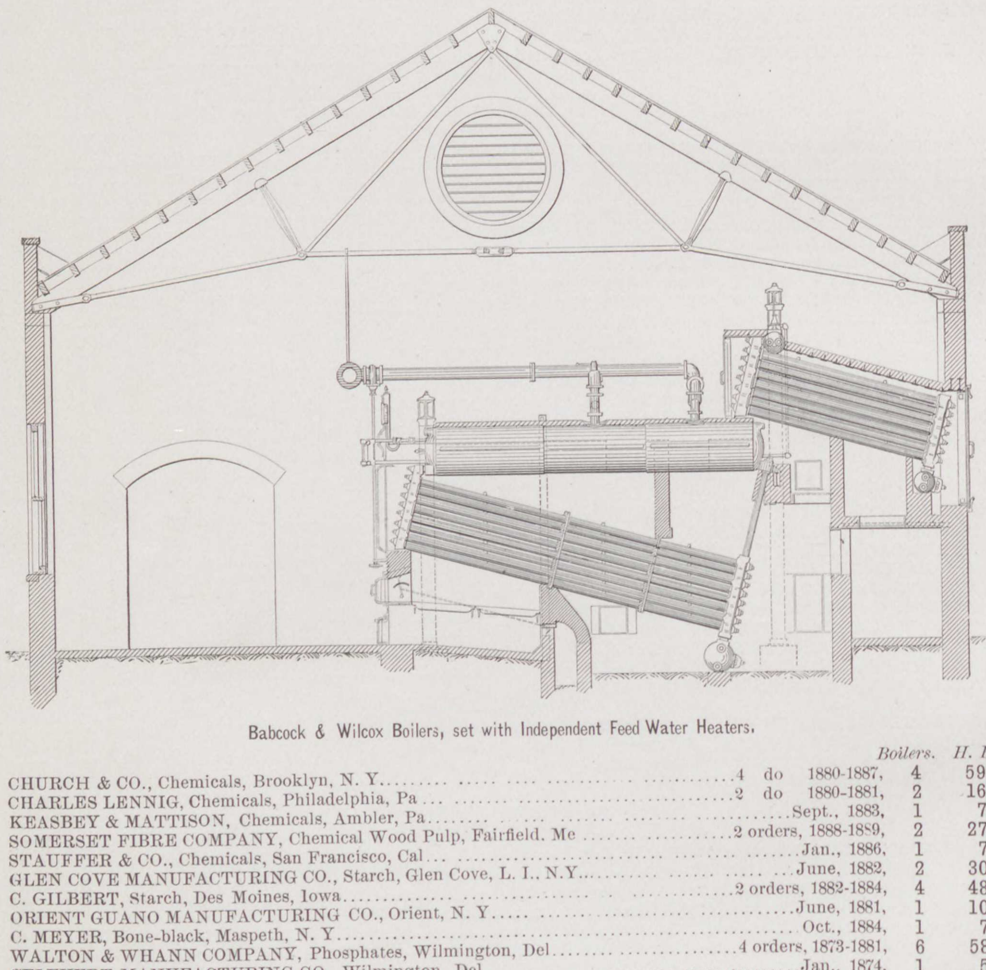
| | | Boilers. | H. P. |
|---|---|---|---|
| NEW YORK & BROOKLYN BRIDGE, Brooklyn, New York | 2 orders, 1882-1886, | 6 | 624 |
| CHICAGO CITY RAILROAD, Chicago, Ill. | April, 1881, | 4 | 1000 |
| ST. PAUL CITY RAILWAY COMPANY, St. Paul, Minn. | Sept., 1888, | 3 | 624 |
| GRAND AVENUE RAILWAY COMPANY, Kansas City, Mo. | 2 orders, 1886-1888, | 4 | 800 |
| METROPOLITAN STREET RAILWAY COMPANY, Kansas City, Mo. | 3 do 1886-1888, | 9 | 1800 |
| INTERSTATE CONSOLIDATED RAPID TRANSIT RAILWAY CO., Kansas City, Mo. | Aug., 1887, | 2 | 400 |
| PEOPLE'S CABLE RAILWAY COMPANY, Kansas City, Mo. | Aug., 1887, | 3 | 600 |
| DENVER CITY CABLE RAILWAY COMPANY, Denver, Col. | Jan., 1889, | 3 | 1200 |
| MARKET STREET CABLE RAILWAY, San Francisco., Cal. | 2 orders, 1882-1887, | 6 | 1500 |
| PATENT CABLE TRAMWAY CORPORATION, London, England<br>do Edinburgh, Scotland | Aug., 1883,<br>Dec., 1886, | 2 | 240 |
| STEEP GRADE CABLE TRAMWAY COMPANY, Highgate, London, England | Sept., 1884, | 1 | 51 |
| THE MELBOURNE TRAMWAYS, Richmond Line, Australia, Melbourne<br>do Fitzroy Line, do | Nov., 1884,<br>July, 1885, | 6 | 1040 |

## RAILROADS.

| | | Boilers. | H. P. |
|---|---|---|---|
| PENNSYLVANIA RAILROAD CAR SHOPS, Hoboken, N. J. | May, 1883, | 2 | 102 |
| CENTRAL RAILROAD OF NEW JERSEY, Jersey City, N. J. | Oct., 1888, | 4 | 368 |
| SEABOARD & ROANOKE RAILROAD, Portsmouth, Va. | Jan., 1888, | 2 | 146 |
| LAKE ERIE & WESTERN RAILROAD, Lima, Ohio | Sept. 1880, | 2 | 100 |
| TOLEDO & OHIO CENTRAL RAILROAD, Bucyrus, Ohio | Oct., 1880, | 2 | 100 |
| FLINT & PÈRE MARQUETTE RAILROAD, CAR SHOPS, East Saginaw, Mich. | April, 1881, | 2 | 500 |
| CHICAGO, BURLINGTON & QUINCY RAILROAD, Burlington and Ottumwa, Iowa,<br>do do Chicago, Ill. | 3 orders, 1881-1888, | 6 | 564 |
| ST. PAUL & NORTHERN PACIFIC RAILROAD, Como Shops, Minn. | 2 do 1885-1887, | 6 | 624 |
| MINNESOTA & NORTH WESTERN RAILROAD, St. Paul, Minn. | 2 do 1886-1887, | 4 | 408 |
| NORTHERN PACIFIC TERMINAL COMPANY, Albina Shops, Oregon | Feb., 1884, | 6 | 720 |
| COMPAGNIE DES TRAMWAYS DU DÉPARTEMENT DU NORD, Roubaix, France | June, 1886, | 3 | 135 |
| COMPAGNIE DES OMNIBUS ET TRAMWAY, Lyons, France | 2 orders, 1887-1888, | 3 | 152 |
| LIMA & ORRYA RAILWAY COMPANY, Callao, Peru, S. A. | July, 1871, | 3 | 115 |
| CHIMBOTE RAILWAY COMPANY, Chimbote, Peru, S. A. | April, 1872, | 2 | 50 |
| MOSCOW KURSK RAILROAD, Moscow, Russia | 2 orders, 1886, | 2 | 134 |

# OILS, GLUE, AND CHEMICAL WORKS.

| | | Boilers. | H. P. |
|---|---|---|---|
| STANDARD OIL COMPANY, Bayonne, N. J., and elsewhere | 36 orders, 1880-1886, | 45 | 6634 |
| BROOKLYN OIL REFINERY, Brooklyn, N. Y. | 3 do 1879-1882, | 6 | 728 |
| PRATT MANUFACTURING CO., Brooklyn, N. Y. | 6 do 1881-1886, | 9 | 1482 |
| SONE & FLEMING MANUFACTURING CO., Brooklyn, N. Y. | 2 do 1882-1887, | 4 | 416 |
| CHESEBROUGH MANUFACTURING CO., Brooklyn, N. Y. | 2 do 1881-1883, | 2 | 245 |
| HOWE LARD OIL COMPANY. Long Island City, N. Y. | May, 1882, | 2 | 120 |
| LOMBARD, AYRES & CO., Oil Refinery, Bayonne, N. J. | 15 orders, 1879-1888, | 15 | 2246 |
| NATIONAL TRANSIT COMPANY, Pipe Line, Rutherford Park, N. J. | 2 orders, Feb. and Dec., 1881, | 5 | 520 |
| ATLANTIC REFINING COMPANY, Philadelphia, Pa. | 5 do 1881-1886, | 7 | 1111 |
| BELMONT OIL WORKS, Philadelphia, Pa. | 2 do 1881-1885, | 2 | 333 |
| ORR, LEONARD & CUMMINGS, Oil, Philadelphia, Pa. | Mar. 1884, | 1 | 104 |
| BALTIMORE UNITED OIL COMPANY, Baltimore, Md. | Dec., 1886, | 1 | 120 |
| MAGINNIS OIL MILL, New Orleans, La. | July, 1882, | 2 | 360 |
| GEO. UPTON, Glue, Peabody, Mass. | 2 do 1882-1884, | 2 | 280 |
| PETER COOPER'S GLUE FACTORY, Brooklyn, N. Y. | 2 do 1880-1881, | 4 | 500 |
| BAEDER, ADAMSON & CO., Glue, Philadelphia, Pa. | 5 do 1879-1883, | 7 | 979 |
| do Newark, N. J. | May, 1884, | 1 | 136 |
| OLIVER JOHNSON & CO., Paints, Drugs, &c., Providence, R. I. | July, 1884, | 1 | 51 |
| RUMFORD CHEMICAL WORKS, Providence, R. I. | 2 orders, 1880-1885, | 4 | 283 |



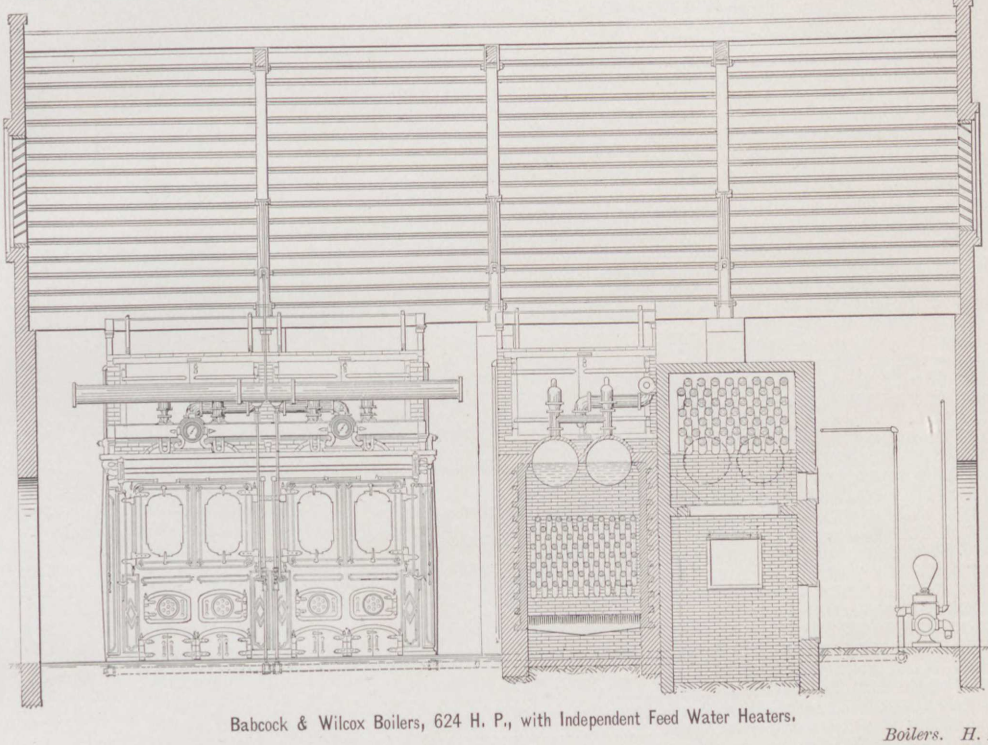
Babcock & Wilcox Boilers, set with Independent Feed Water Heaters.

| | | Boilers. | H. P. |
|---|---|---|---|
| CHURCH & CO., Chemicals, Brooklyn, N. Y. | 4 do 1880-1887, | 4 | 592 |
| CHARLES LENNIG, Chemicals, Philadelphia, Pa. | 2 do 1880-1881, | 2 | 166 |
| KEASBEY & MATTISON, Chemicals, Ambler, Pa. | Sept., 1883, | 1 | 75 |
| SOMERSET FIBRE COMPANY, Chemical Wood Pulp, Fairfield, Me. | 2 orders, 1888-1889, | 2 | 276 |
| STAUFFER & CO., Chemicals, San Francisco, Cal. | Jan., 1886, | 1 | 73 |
| GLEN COVE MANUFACTURING CO., Starch, Glen Cove, L. I., N.Y. | June, 1882, | 2 | 300 |
| C. GILBERT, Starch, Des Moines, Iowa | 2 orders, 1882-1884, | 4 | 488 |
| ORIENT GUANO MANUFACTURING CO., Orient, N. Y. | June, 1881, | 1 | 104 |
| C. MEYER, Bone-black, Maspeth, N. Y. | Oct., 1884, | 1 | 73 |
| WALTON & WHANN COMPANY, Phosphates, Wilmington, Del. | 4 orders, 1873-1881, | 6 | 587 |
| CELEVERT MANUFACTURING CO., Wilmington, Del. | Jan., 1874, | 1 | 50 |
| PENDLETON GUANO COMPANY, Atlanta, Ga. | Sept., 1881, | 1 | 104 |
| CORNWALL & BROTHER, Soaps and Candles, Louisville, Ky. | 4 do 1874-1883, | 4 | 225 |
| MICHIGAN CARBON WORKS, Detroit, Mich. | 3 do 1881-1885, | 4 | 500 |
| PRUSSING VINEGAR COMPANY, Chicago, Ill. | Nov., 1881, | 1 | 104 |
| N. K. FAIRBANKS & CO., Lard, St. Louis, Mo. | Oct., 1888, | 1 | 140 |
| THE SOLVAY PROCESS COMPANY, Soda, Syracuse, N. Y. | 7 orders, 1882-1888, | 21 | 4556 |
| SOLVAY & CIE., Whylen, Grand Duché de Baden | 2 do 1881-1882, | 10 | 1220 |
| do Dombasle sur Murthe, France | 2 do 1881-1882, | | |
| do Coaillet, Belgium | Aug., 1883, | | |

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| YOUNG'S PARAFFINE LIGHT & MINERAL OIL CO., Addiewell, Scotland | Sept., 1883, | 1 | 120 |
| J. & G. COX, Glue and Gelatine, Edinburgh, Scotland | 2 orders, 1882-1886, | 2 | 146 |
| JAMES ROSS & CO., Falkirk, Scotland | Sept., 1883, | 1 | 82 |
| BROXBURN OIL COMPANY, Broxburn, Scotland | May, 1883, | 1 | 140 |
| FARQUHAR & GILL, Aberdeen, Scotland | Mar., 1887, | 1 | 40 |
| PRENTICE BROTHERS, Artificial Manures, Stowmarket, Eng | Oct., 1888. | 1 | 105 |
| M. DUBOIS, Chemicals, St. Denis, France | June, 1885, | 1 | 61 |
| PH. LEYSEN FILS, Starch, Vesuiet, France | Mar., 1886, | 2 | 240 |
| DAIRE, E. ANSELIN & CO., Soap, Arras, France | Oct., 1886, | 1 | 35 |
| GILLIARD, MOUNET ET CARTIER, Chemicals, Lyons, France | Dec., 1886, | 2 | 240 |
| A. GERMOT, Chemicals, Argenteuil, France | Mar., 1887, | 1 | 25 |
| MALEZIEUX & CO., Chemicals, Bondy, near Paris, France | April, 1887, | 1 | 120 |
| MATTEO DUBICH, Oil, Trieste, Austria | June, 1886, | 1 | 145 |
| THE NEWSKY STEARINE CANDLE FACTORY, Moscow, Russia | Sept., 1886, | 2 | 70 |
| "LA PALMA" FABRICA Y REFINERIA DE ACEITA DE COCO, Baracoa, Cuba | Nov., 1888, | 1 | 73 |

## COTTON MILLS.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| LOCKWOOD COMPANY, Waterville, Me | June, 1881, | 2 | 309 |
| COCHECO MANUFACTURING CO., Dover, N. H | July, 1881, | 2 | 164 |
| OEL H. GATES & CO., Burlington Cotton Mills, Burlington, Vt | March, 1883, | 2 | 244 |



Babcock & Wilcox Boilers, 624 H. P., with Independent Feed Water Heaters.

| | | *Boilers.* | *H. P.* |
|---|---|---|---|
| ARLINGTON MILLS, Lawrence, Mass | Feb., 1887, | 12 | 2880 |
| BARNABY MANUFACTURING CO., Fall River, Mass | March, 1882, | 4 | 448 |
| HEBRON MANUFACTURING CO., Attleboro, Mass | March, 1882, | 4 | 400 |
| MANCHAUG COMPANY, Manchaug, Mass | June, 1882, | 4 | 400 |
| HADLEY COMPANY, Thread, Holyoke, Mass | 2 orders, 1883-1886, | 2 | 197 |
| B. B. & R. KNIGHT, Providence & Natick, R. I | 4 do 1884-1886, | 8 | 1710 |
| NOTTINGHAM MILLS, Providence, R. I | 2 do 1884-1885, | 4 | 416 |
| PEACEDALE MANUFACTURING CO., Peacedale, R. I | July, 1882, | 2 | 280 |
| CUTLER MANUFACTURING CO., Yarn and Cotton Cordage, Warren, R. I | Jan., 1883, | 1 | 92 |
| PALMER BROTHERS, Montville and Oakdale Mills, Montville, Conn | 2 orders, 1879-1882, | 2 | 120 |
| FALLS COMPANY, Norwich, Conn. | 3 do 1881-1882, | 4 | 368 |
| PONEMAH MILLS, Taftville, Norwich, Conn | 2 do 1882-1883, | 4 | 400 |
| QUINNEBAUG COMPANY, Danielsonville, Conn | 2 do 1882-1883, | 5 | 518 |
| WHITE MANUFACTURING CO., Rockville, Conn | June, 1887, | 1 | 136 |
| ONECO MANUFACTURING CO., New London, Conn | June, 1888, | 2 | 208 |
| IRVING MANUFACTURING CO., New Brighton, S. I., N. Y | Sept, 1883, | 1 | 92 |
| T. H. SMITH, Jamestown Cotton Mill, Jamestown, N. Y. | Sept., 1880, | 2 | 160 |
| MILLVILLE MANUFACTURING CO., Millville, N. J | Oct., 1881, | 1 | 104 |
| HENRY McKEEN & CO., S. Easton, Pa | Mar., 1882, | 1 | 50 |
| ARLINGTON MILLS MANUFACTURING CO., Wilmington, Del. | Aug., 1880, | 4 | 500 |

| | | Boilers. | H. P. |
|---|---|---|---|
| MOUNT VERNON MILLS, Baltimore, Md | Mar., 1882, | 4 | 500 |
| W. H. BALDWIN, JR., & CO., Savage, Md | Aug., 1881, | 2 | 500 |
| RANDELMAN MANUFACTURING CO., Randelman, N. C | Aug., 1887, | 1 | 51 |
| F. & H. FRIES, Salem, N. C | 2 orders, 1880-1881, | 2 | 250 |
| CHARLOTTE COTTON MILLS, Charlotte, N. C | 2 do 1881-1886, | 4 | 301 |
| GASTONIA COTTON MANUFACTURING CO., Gastonia, N. C., | Feb., 1888, | 1 | 82 |
| HUGUENOT MILLS, Greenville, S. C | 2 orders, 1882-1886, | 2 | 100 |
| SUMTER COTTON MILLS, Sumter, S. C | Jan. 1881, | 1 | 75 |
| J. J. DALE & CO., St. Helena Island, S. C | June, 1880, | 1 | 50 |
| NEWBERRY COTTON MILLS, Newberry, S. C | 2 orders, 1883-1887, | 3 | 480 |
| REEDY RIVER MANUFACTURING CO., Reedy River Factory, S. C | Jan., 1884, | 1 | 51 |
| DARLINGTON MILLS, Darlington, S. C | April, 1884, | 2 | 272 |
| THE SWIFT MANUFACTURING CO., Columbus, Ga | 3 orders, 1883-1887, | 5 | 511 |
| EXPOSITION COTTON MILL, Atlanta, Ga | Feb., 1882, | 2 | 208 |
| FULTON COTTON SPINNING COMPANY, Atlanta, Ga | 3 orders, 1881-1886, | 4 | 602 |
| BIBB MANUFACTURING COMPANY, Macon, Ga | Nov., 1887, | 1 | 208 |
| MADISON COTTON GINNING COMPANY, Madison, Fla | July, 1882, | 1 | 60 |
| ADAMS COTTON MILLS, Montgomery, Ala | 2 orders, 1881-1887, | 2 | 117 |
| MAGINNIS COTTON MILLS, New Orleans, La | 5 do 1882-1888, | 14 | 2544 |
| FLINT COTTON & WOOLEN MANUFACTURING CO., Flint, Mich | Aug., 1881, | 1 | 82 |
| CALIFORNIA COTTON MILLS, Oakland, Cal | Jan., 1884, | 2 | 208 |
| MONCTON COTTON MANUFACTURING CO., Moncton, N. B | Sept., 1882, | 2 | 300 |
| WALTER CRUM & CO., Thornliebank, Scotland | Feb , 1883, | 1 | 122 |
| THOMSON & ROBERTSON, Milngavie, Scotland | July, 1883, | 1 | 122 |
| F. STEWART SANDEMAN, Stanley, Scotland | Aug., 1883, | 1 | 55 |
| THE EDINBURGH ROPERIE & SAIL CLOTH CO., LIMITED, Leith, Scotland | Aug., 1888, | 1 | 156 |
| JOSEPH SCHOFIELD & CO., Littleborough, Lanc., Eng | Mar., 1885, | 1 | 136 |
| HARTFORD MILLS COMPANY, Preston, England | Sept., 1885, | 1 | 156 |
| PADIHAM SPINNING COMPANY, Padiham, England | Aug., 1885, | 1 | 156 |
| PENDLEBURY & SONS, Radcliffe, England | Feb., 1886, | 1 | 156 |
| R. & H. HINCHCLIFFE, Mytholanroyd, York, England | Sept., 1886, | 1 | 156 |
| THE OAK MOUNT SPINNING & MANUFACTURING CO., Burnley, Eng | May, 1887, | 1 | 124 |
| BOTTERIL, POTTER & CO., Finishers, Bradford, England | May, 1888, | 1 | 124 |
| THE PLATT LANE MANUFACTURING CO., LIMITED Hindley, England | April, 1888, | 1 | 124 |
| FERDINAND BRACQ, Spinner, Ghent, Belguim. | May, 1888, | 1 | 105 |
| WIBAUX MOTTE, Roubaix, France | May, 1885, | 2 | 184 |
| ALLART ROUSSEAU, Carder, Roubaix, France. | Sept., 1885, | 4 | 744 |
| A. PROUVOST & CO., Carders, Roubaix, France | Oct., 1885, | 3 | 558 |
| WIBAUX FLORIN, Twister, Roubaix, France | 2 orders, April & Oct., 1885, | 4 | 544 |
| A. DELADALLE, Roubaix, France | Oct., 1885, | 1 | 186 |
| M. PATTYN, Spinner, Roubaix, France | Dec., 1885, | 1 | 123 |
| C. & J. POLLET, Roubaix, France | Feb., 1887, | 1 | 186 |
| M. COSSERAT, Weaver, Amiens, France | 3 orders, 1885-1887, | 3 | 252 |
| VINCENT PONNIER ET CIE, Sonones, Vosges, France<br>do do Moussey, France | 1 do May, 1885.<br>2 do July, 1885, | 2 | 159 |
| FLIPO FRÈRES, Tourcoing, France | Aug., 1885, | 1 | 166 |
| SCALABRE-DELCOURS FILS, Tourcoing, France | Oct., 1885, | 1 | 76 |
| ALBERT POLLET, Tourcoing, France | Aug., 1885, | 1 | 104 |
| TIBERGHIEN FRÈRES, Carders, Tourcoing, France | 3 orders, 1885-1887, | 5 | 1200 |
| MARTIAL DASSOUVILLE, Tourcoing, France | April, 1886, | 1 | 61 |
| ED. CALAME, Spinner, Epinal, France | Dec., 1884, | 2 | 150 |
| SOCIÉTÉ POUYER-QUERTIE, Spinning, Rouen, France | 2 orders, 1885-1886, | 4 | 512 |
| ARMAND PEYNAUD, Spinner & Weaver, Charleval, France | 2 orders, May & Sept., 1886, | 4 | 480 |
| HELZINGER ET FILS, Weavers, Charleval, France | May, 1886, | 1 | 61 |
| C. ZENTZ ET CIE, Beauvais, France | May, 1886, | 1 | 104 |
| BAUDOIN, RISLER ET CIE., Spinners, Luxeuel, France | Aug., 1886, | 1 | 136 |
| IRÉNÉ BRUN ET CIE, Lace, St. Chamond, France | May, 1888, | 1 | 92 |
| J. PONGS, Jr., Neuwerk, Germany | May, 1885, | 1 | 120 |
| JULIUS RIPPERT, Forst, Germany | Dec., 1886, | 1 | 136 |
| TORRABADILLA HERMANOS, Spinners, Barcelona, Spain | Feb., 1886, | 2 | 90 |
| JOSÉ SALGOT, Weaver, Barcelona, Spain | May, 1885, | 1 | 15 |
| PABLO SAN SALVADOR, Weaver, Barcelona, Spain | May, 1886, | 2 | 40 |
| P. MALJUTIN, Rimenskoje, Russia | July, 1885, | 1 | 92 |
| SAVANA, SOCIÉTÉ ANONYME DE FILATURE ET TISSAGE MÉCANIQUE, Pondichéry, India | 6 orders, 1884-1887, | 8 | 820 |

## WOOL, WORSTED, Etc., MANUFACTURERS.

| | | Boilers. | H. P. |
|---|---|---|---|
| WORUMBO MANUFACTURING CO., Lisbon Falls, Me | May, 1885, | 2 | 272 |
| DAVID R. CAMPBELL, Sangerville, Me | Aug., 1887, | 2 | 122 |
| J. W. BUSIEL & CO., Granite Hosiery Mills, Laconia, N. H | Aug., 1882, | 1 | 82 |
| FRANK P. HOLT, Hosiery, Laconia, N. H | Aug., 1886, | 1 | 73 |
| UNION MANUFACTURING CO., Wolcottsville, Conn | Dec., 1881, | 2 | 200 |
| WARREN WOOLEN COMPANY, Stafford Springs, Conn | 2 orders, Jan., Sept., 1883, | 2 | 228 |
| HALL BROTHERS, Doeskins, Norwich, Conn | Jan., 1884, | 2 | 208 |
| SPRINGVILLE COMPANY, Coatings, Rockville, Conn | June, 1887, | 2 | 244 |
| ROOT MANUFACTURING CO., Hosiery, Cohoes, N. Y | Oct., 1886, | 1 | 51 |
| HARDER KNITTING COMPANY, Hudson, N. Y | Jan., 1882, | 2 | 150 |
| RARITAN WOOLEN MILL, Raritan, N. J | 3 orders, 1878-1886, | 6 | 1060 |
| SOMERSET MANUFACTURING CO., Raritan, N. J | 3 do 1879-1881 | | 720 |

| | | Boilers. | H. P. |
|---|---|---|---|
| BOUND BROOK WOOLEN MILLS, Bound Brook, N. J. | 4 do 1878-1881, | 5 | 695 |
| FAIRMOUNT WORSTED MILLS, Philadelphia, Pa. | 2 do 1879-1882, | 3 | 416 |
| KEYSTONE MILLS, Philadelphia, Pa. | Dec., 1879, | 2 | 150 |
| M. A. FURBISH & SON, Philadelphia, Pa. | Sept., 1880, | 4 | 500 |
| PENN WORSTED MILLS, Philadelphia, Pa. | 2 orders, 1883-1886, | 2 | 212 |
| LEWIS S. COX & CO., Knit Goods and Ladies' Suits, Philadelphia, Pa | Oct., 1883, | 2 | 150 |
| THOMAS JAGGERS, Yarns, Philadelphia, Pa. | April, 1883, | 1 | 104 |
| JONATHAN RING & SON, Yarns, Philadelphia, Pa. | 2 orders, 1883-1888, | 2 | 208 |
| J. C. GRAHAM, Dress Trimmings, Philadelphia, Pa. | Nov., 1885, | 1 | 73 |
| CONSHOHOCKEN WORSTED MILLS, Conshohocken, Pa. | 3 orders, 1881-1883, | 5 | 824 |
| THE F. GRAY COMPANY, Piqua, Ohio | Mar., 1885, | 1 | 104 |
| S. B. WILKINS COMPANY Rockford, Ill. | 2 orders, 1881-1887, | 2 | 121 |
| EAGLE KNITTING COMPANY, Elkhart, Ind. | 2 do 1882-1887, | 2 | 100 |
| OLD KENTUCKY WOOLEN MILLS, Louisville, Ky. | 2 do 1883-1887, | 3 | 312 |
| COOPER, WELLS & CO., St. Joseph, Mich. | Jan., 1883, | 1 | 83 |
| THE BUELL MANUFACTURING CO., St. Joseph, Mo. | Mar., 1883, | 1 | 150 |
| ROSAMOND WOOLEN MILLS, Almont, Ont., Canada | 2 orders, 1878-1883, | 5 | 362 |
| MONTREAL WOOLEN MILLS, Montreal, Canada | Mar., 1888, | 1 | 108 |
| CHARTERIES, SPENCE & CO., Tweeds, Dumfries, Scotland | Aug., 1886, | 1 | 120 |
| CAULLIEZ PÈRE, FILS & DELAOUTRE, Tourcoing, France | June, 1887, | 2 | 488 |
| LÉON PEQUIN, Cuygand la Bernardière, Vendée, France | July, 1888, | 1 | 40 |
| DEVAUX FRÈRES ET CIE, Adrimont, Verdiers, Belgium | Sept., 1888, | 1 | 75 |
| JOHN BOUTIKOFF, Weaver & Spinner, Moscow, Russia | July, 1885, | 2 | 164 |
| ALBERT HUBNER, Weaver, Moscow, Russia | Feb., 1885. | 1 | 45 |
| EGERTON WOOLEN MILLS, Dharival, Punjab, India | Oct., 1886, | 1 | 120 |

## SILK MILLS.

| | | Boilers. | H. P. |
|---|---|---|---|
| CHENEY BROTHERS, South Manchester, Conn | Oct., 1880, | 2 | 300 |
| LOUIS FRANKE & CO., Paterson, N. J. | April, 1880, | 2 | 150 |
| S. MEYENBERG, Hoboken, N. J. | Nov., 1880, | 1 | 75 |
| ONEIDA COMMUNITY, Limited, Community, N. Y | Mar., 1888, | 1 | 61 |
| F. S. DALE, Whitehall, N. Y. | Sept., 1888, | 1 | 75 |
| CORRIVEAU & CO., Montreal, Canada | Jan., 1882, | 1 | 100 |
| JAMES MELVILLE & SONS, Hazelden, Mearns, Scotland | May, 1883, | 1 | 104 |
| LISTER & CO., MANNINGHAM MILLS, Bradford, England | Feb., 1885, | 1 | 136 |
| MOTTE BOSSUT FILS, Velvets, Leers, France | Aug., 1885, | 1 | 136 |
| CHRISTOPH ANDREAL, Mülheim-on-Rhine, Germany | Aug., 1884, | 1 | 120 |

## HEMP, FLAX, Etc.

| | | Boilers. | H. P. |
|---|---|---|---|
| LAWRENCE ROPE WORKS, Brooklyn, N. Y. | 2 orders, 1879-1886, | 2 | 250 |
| L. WATERBURY & CO., Rope, Brooklyn, N. Y. | Jan., 1880, | 4 | 350 |
| W. O. DAVEY & SONS, Oakum, Jersey City, N. J. | 2 orders, 1880-1881, | 3 | 300 |
| R. J. PATRULIO, Hemp, Progreso, Mexico | Jan., 1879, | 1 | 60 |
| F. STEWART SANDEMAN, Jute Mill, Dundee, Scotland | Aug., 1883, | 1 | 136 |
| JAMES R. CAIRD, Flax and Jute, Dundee, Scotland | June, 1887, | 2 | 272 |
| THOS. BRIGGS, Salford, England | Nov., 1885, | 1 | 124 |
| MOREL & VERBEKE, Flax Spinners, Gand, Belgium | June, 1888, | 1 | 163 |
| JAMES MILLER & CO., Rope Mfg., Melbourne, Australia | Sept., 1888, | 1 | 312 |

## CARPETS AND OIL CLOTHS.

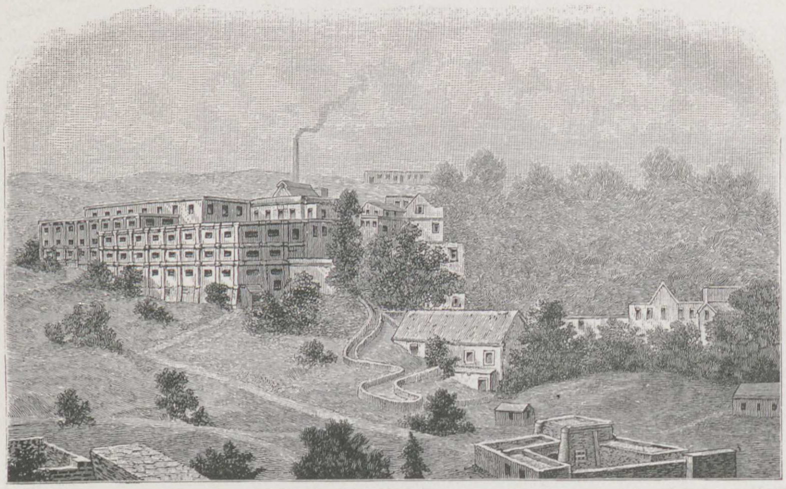
| | | Boilers. | H. P. |
|---|---|---|---|
| ALEX. SMITH & SONS CARPET COMPANY, Yonkers, N. Y | 6 orders, 1883-1888, | 8 | 1504 |
| CALEDONIA CARPET MILLS, Philadelphia, Pa. | Oct., 1883, | 4 | 416 |
| WM. WHITAKER & SONS, Philadelphia, Pa. | 2 orders, 1879-1883, | 4 | 500 |
| A. SAMPSON & SONS, Oil-cloths, Newtown, L. I., N. Y. | Aug., 1882, | 2 | 208 |
| JOHN BARRY, OSTLERE & CO., Linoleum, Kirckaldy, Scotland | 4 orders, 1884-1888, | 5 | 1040 |
| MITCHELL BROTHERS, Waterfoot, England | Oct., 1885, | 2 | 248 |
| THOS. BRIGGS, Oil-cloth, Salford, England | 2 orders, 1885-1888, | 2 | 248 |

## LEATHER.

| | | Boilers. | H. P. |
|---|---|---|---|
| JEWELL BELTING COMPANY, Hartford, Conn. | July, 1883, | 2 | 164 |
| HOWELL, HINCHMAN & CO., Middletown, N. Y. | Aug., 1883, | 2 | 164 |
| T. P. HOWELL & CO., Newark, N. J. | 3 orders, 1883-1886, | 3 | 244 |
| J. MUNDELL & CO., Shoes, Philadelphia, Pa. | Dec., 1877, | 1 | 40 |
| WM. FOREPAUGH & BROTHER, Tannery, Philadelphia, Pa | Jan., 1881, | 2 | 120 |
| PUSEY & SCOTT COMPANY, Morocco Mfrs., Wilmington, Del. | Aug., 1872, | 1 | 75 |
| H. S. ROBINSON & BURTENSHAW, Boots and Shoes, Detroit, Mich. | Mar., 1884, | 2 | 120 |
| PINGREE & SMITH, Boots and Shoes, Detroit, Mich. | July, 1884, | 1 | 120 |
| CITY OF KEOKUK, Leather Mfg., Keokuk, Iowa | July, 1888, | 2 | 90 |
| WM. WHITMORE, Tanner, Bermondsey, London, England | Dec., 1884, | 2 | 120 |
| W. R. BRAY, Currier, Bermondsey, London, England | Oct., 1886, | 1 | 82 |
| WHITMORE & SONS, Tanners, Edenbridge, Kent, England | Nov., 1885, | 1 | 100 |
| RYMER & SHEPARD, Tanners, Northampton, England | Feb., 1886, | 1 | 84 |
| A. M. DORMAN, Tanner, Maidstone, Kent, England | Dec., 1887, | 1 | 86 |
| BEARE & SONS, Tanners, Norwich, England | Dec., 1887, | 1 | 65 |
| ULYSSE DÉON, Tanner, Sens, France | Jan., 1887, | 1 | 51 |

# PAPER AND PRINTING.

| | | Boilers. | H. P. |
|---|---|---|---|
| CUMBERLAND & PRESUMPSCOT MILLS, Cumberland, Me | 3 orders, 1883-1888, | 9 | 952 |
| S. D. WARREN & CO., Copsecook Mills, Gardner, Me | July, 1884, | 2 | 184 |
| FOREST PAPER COMPANY, Yarmouthville, Me | 3 orders, 1883-1889, | 5 | 1344 |
| MONADNOCK MILLS, Bennington, N. H | Dec., 1883, | 1 | 61 |
| S. Y. BEACH PAPER COMPANY, Seymour, Conn | April, 1872, | 1 | 60 |
| AMERICAN BANK NOTE COMPANY, New York | Sept., 1884, | 2 | 240 |
| WAIT & RICHARDS, Sandy Hill, N. Y. | Aug., 1883, | 2 | 164 |
| CHAS. VAN BENTHUYSEN & SONS, Printers, Albany, N. Y | Aug., 1883, | 1 | 73 |
| D. A. BULLARD & SONS, Schuylerville, N. Y | April, 1884, | 1 | 122 |
| WM. C. HAMILTON & SONS, Lafayette, Pa | Oct., 1881, | 8 | 1000 |
| MARTIN & W. H. NIXON, Manayunk, Philadelphia, Pa | 6 orders, 1881-1884, | 13 | 1749 |
| J. K. WRIGHT & CO., Printers' Inks, Philadelphia, Pa | Sept., 1882, | 1 | 50 |
| GEO. S. HARRIS & SONS, Printers, Philadelphia, Pa | May, 1881, | 1 | 75 |
| DAGER & COX, Paper, Bridgeport, Pa | 2 orders, 1883-1884, | 2 | 196 |
| PENNSYLVANIA PULP & PAPER COMPANY, Lock Haven, Pa | Dec., 1883, | 2 | 164 |
| WESTMORELAND PAPER COMPANY, West Newton, Pa | 2 orders, 1884-1888, | 4 | 752 |
| PHILADELPHIA LEDGER PAPER MILLS, Elkton, Md | Oct., 1872, | 2 | 100 |
| CECIL PAPER COMPANY, Limited, Elkton, Md | Aug., 1883, | 1 | 60 |
| SUSQUEHANNA WATER POWER & PAPER CO., Conowingo, Md | 2 orders, 1883-1884, | 4 | 328 |
| FARM & FIRESIDE, Springfield, O | July, 1881, | 1 | 50 |
| WARDLOW THOMAS PAPER COMPANY, Middletown, O | 3 orders, 1881-1883, | 4 | 490 |
| TYTUS PAPER COMPANX, Middletown, O | 2 do 1882-1883, | 3 | 625 |
| GARDNER PAPER COMPANY, Middletown, O | Oct., 1886, | 2 | 250 |
| THE W. B. OGLESBY PAPER COMPANY, Middletown, O | Aug., 1888, | 1 | 146 |



Paper Mill of Juan M. Benfield, City of Mexico.

| | | Boilers. | H. P. |
|---|---|---|---|
| EAGLE PAPER COMPANY, Franklin, O | 2 orders, 1883-1888, | 3 | 375 |
| PORTAGE STRAW BOARD COMPANY, Circleville, O | Sept., 1883, | 16 | 1472 |
| GLASS EDSELL PAPER COMPANY, Delaware, Ohio | 2 orders, 1883-1887, | 3 | 258 |
| VAN NORTWICK PAPER COMPANY, Batavia, Ill. | July, 1888, | 1 | 125 |
| KAUKAUNA PAPER COMPANY, Kaukauna, Wis | July, 1888, | 2 | 250 |
| CEDAR FALLS PAPER COMPANY, Cedar Falls, Ia | 2 orders, 1882-1883, | 2 | 197 |
| KANSAS CITY JOURNAL, Kansas City, Mo | Mar., 1887, | 2 | 200 |
| LICK PAPER COMPANY, Agnews, Cal | 2 orders, 1883-1884, | 3 | 256 |
| JUAN M. BENFIELD, Paper, City of Mexico, Mex | June, 1887, | 1 | 122 |
| JOHN COLLINS, Denny, Scotland | 4 orders, 1885-1888, | 5 | 561 |
| do Milton Paper W'ks, Dowling, Scotland, | Nov., 1885, | 1 | 104 |
| MARTIN & CO., LIMITED, Millboard Mfrs., Craiginarlock, Scotland | Oct., 1883, | 1 | 82 |
| BROWN, STEWART & CO., Greenock, Scotland | Mar., 1886, | 1 | 156 |
| ALEXANDER MARR, Newspaper, Aberdeen, Scotland | Feb., 1888, | 2 | 50 |
| GORDON'S MILLS PAPER COMPANY, Aberdeen, Scotland | June, 1888, | 2 | 280 |
| S. H. COWELL, Printer, Ipswich, England | Mar., 1883, | 1 | 35 |
| J. WESTCOTT & SONS, Paper, Workingham, England | Oct., 1884, | 1 | 54 |
| GRANT & CO., Printers, London, England | Nov., 1884, | 1 | 81 |
| SPICER BROTHERS, Paper, London, England | Oct., 1885, | 1 | 20 |
| W. & A. TREMLET, Paper, Exeter, England | 2 orders, 1885-1887, | 2 | 291 |
| JOHN DICKINSON & CO., LIMITED, Hemel Hempstead, England | 2 orders, Jan. & Sept., 1887, | 4 | 720 |
| TAKATA & CO., London, for Paper Mill, Japan | Dec., 1887, | 3 | 349 |
| EVANS & McEWEN, Cardiff, Wales | Dec., 1887, | 1 | 140 |
| CHAS. UNSINGER, Printer, Paris, France | Nov., 1886, | 1 | 50 |
| IMPRIMERIE FRANÇAISE, Paris, France | Jan., 1888, | 2 | 126 |
| CHARLES SCHLAEBER, Printer, Paris, France | Oct., 1888, | 3 | 120 |

| | | Boilers. | H. P. |
|---|---|---|---|
| PAUL VARIN, Jean d'Heurs, France | July, 1887, | 2 | 222 |
| ARRA Y CIA, Paper, Tolosa, Spain | Feb., 1886, | 1 | 51 |
| RICART Y CIA, Paper, Villanueva, Spain | Jan., 1886, | 1 | 61 |
| LA VIUDA BORE, Castelfullit, Spain | Oct., 1886, | 1 | 30 |
| NEUSSER PAPER WORKS, Neuss, Germany | April, 1886, | 2 | 208 |
| A. EDLMANN & CO., Bologna, Italy | Nov., 1885, | 1 | 82 |

## LUMBER AND WOOD WORKING.

| | | Boilers. | H. P. |
|---|---|---|---|
| EAGLE SQUARE MANUFACTURING CO., So. Shaftsbury, Vt | Sept., 1883, | 2 | 184 |
| WOONSOCKET SPOOL & BOBBIN CO., Woonsocket, R. I | April, 1885, | 2 | 146 |
| UNITED STATES VULCANIZING WOOD & LUMBER COMPANY, New York | Mar., 1882, | 2 | 150 |
| NEW YORK LUMBER & WOOD WORKING COMPANY, New York City | April, 1883, | 2 | 165 |
| HARDY & VOORHEES, Planing Mill, Brooklyn, N. Y | Jan., 1881, | 1 | 100 |
| ANDRESEN BLATT FOLDING BED COMPANY, Brooklyn, N. Y | Jan., 1883, | 1 | 82 |
| WHITE, POTTER & PAIGE MANUFACTURING CO., Mouldings, Brooklyn, N. Y | May, 1883, | 2 | 122 |
| S. D. KENDRICK, Saw Mill, Glens Falls, N. Y | May, 1887, | 1 | 51 |
| HALL & GARRISON, Philadelphia, Pa | April, 1882, | 2 | 150 |
| ALBERT STOVER, Kintnersville, Pa | Aug., 1881, | 1 | 40 |
| WASHBURN & ZERFASS, Planing Mill, Scranton, Pa | Feb., 1884, | 1 | 61 |
| J. E. PATTERSON & CO., Planing Mill, etc., Pittston, Pa | Sept., 1885, | 2 | 208 |
| KIMBALL, TYLER & CO., Barrel Staves, etc., Baltimore, Md | Mar., 1882, | 1 | 86 |
| E. W. HORSTMEIER & SON, Baltimore, Md | Feb., 1883, | 1 | 146 |
| BRUMBY & BROTHER, Marietta, Ga | Jan., 1882, | 1 | 50 |
| PINNEO & DANIELS, Dayton, O | Nov., 1881, | 2 | 200 |
| DELPHI PLANING MILL & HOOP COMPANY, Delphi, Ind | Jan., 1883, | 1 | 61 |
| SOUTH BEND TOY MANUFACTURING COMPANY, South Bend, Ind | 2 orders, 1884-1887, | 2 | 197 |
| WABASH SCHOOL FURNITURE COMPANY, Wabash, Ind | Mar., 1884, | 1 | 125 |
| INDIANA FURNITURE MANUFACTURING CO., Connersville, Ind | July, 1885, | 2 | 146 |
| DODGE MANUFACTURING CO., Pulleys, etc., Mishawaka, Ind | June, 1888, | 2 | 272 |
| V. BEALE COMPANY, Cobden, Ill | May., 1883, | 1 | 71 |
| BAUERLE & STARK, Sewing Machine Furniture, Chicago, Ill | Jan., 1885, | 1 | 136 |
| R. G. PETERS, Saw Mill, Manistee, Mich | Oct., 1881, | 2 | 500 |
| MARINE CITY STAVE COMPANY, Marine City, Mich | June, 1883, | 2 | 200 |
| SAGINAW CHAIR COMPANY, Saginaw, Mich | Feb., 1884, | 1 | 250 |
| CHESBROUGH BROTHERS, Saw Mill, Taquemenaw River, Mich | May, 1884, | 3 | 312 |
| ST. LOUIS REFRIGERATOR & WOODEN GUTTER CO., St. Louis, Mo | Aug., 1887, | 1 | 240 |
| FORT MADISON CHAIR COMPANY, Fort Madison, Iowa | April, 1882, | 1 | 125 |
| MANN BROTHERS, Milwaukee, Wis | Aug., 1882, | 1 | 60 |
| SHEBOYGAN MANUFACTURING COMPANY, Sheboygan, Wis | Mar., 1883, | 1 | 208 |
| CROCKER CHAIR COMPANY, Sheboygan, Wis | May, 1882, | 1 | 128 |
| FROST PETERSON VENEER SEAT COMPANY, Sheboygan, Wis | May, 1883, | 2 | 125 |
| PAINE LUMBER COMPANY, Oshkosh, Wis | Feb., 1884, | 2 | 416 |
| BROWNLEE & CO., City Saw Mill, Glasgow, Scotland | Jan., 1884, | 1 | 216 |
| ALEXANDER McEWEN, Saw Mill, Wick, Scotland | Mar., 1886, | 1 | 146 |
| MARCUS MOXHAM & CO., Saw Mills, Swansea, So. Wales | Mar., 1885, | 1 | 104 |
| RAVERDEAU, ALLAIRE ET CIE., Romilly, France | April, 1886, | 1 | 51 |
| MONTREUIL SAW MILL, Rouen, France | April, 1886, | 1 | 40 |
| MONTREUIL ET CIE., Saw Mill, Petit-Quevilly, France | May, 1888, | 1 | 82 |

## DYE WORKS AND BLEACHERIES.

| | | Boilers. | H. P. |
|---|---|---|---|
| JAMES MARTIN & CO., Philadelphia, Pa | 2 orders, 1880-1881, | 2 | 208 |
| QUAKER CITY DYE WORKS COMPANY, Philadelphia, Pa | Sept., 1881, | 2 | 272 |
| JAMES McLARDIE & SONS, Paisley, Scotland | 2 orders, 1883-1886, | 2 | 187 |
| HEPBURN & CO., Ramsbottom, Scotland | Jan., 1884, | 1 | 136 |
| P. & P. CAMPBELL, Perth, Scotland | April, 1886, | 1 | 146 |
| JAMES SMITH & SONS, Yarn Dyers, Heywood, England | Oct., 1884, | 1 | 120 |
| J. & J. M. WORRALL, Manchester, Eng | 3 orders, 1884-1887, | 5 | 636 |
| S. SCHWABE & CO., Bleachers, Manchester, England | Dec., 1886, | 2 | 186 |
| HANNART FRÈRES, Roubaix & Wasquehal, France | 4 orders, 1885-1886, | 5 | 826 |
| BROWAEYS-DEGEYTER FRÈRES, Roubaix, France | 2 do 1885-1887, | 2 | 346 |
| ERNOULT BAYART, Dyer, Roubaix, France | Nov., 1885, | 1 | 186 |
| E. ROUSSEL, Dyer, Roubaix, France | 2 orders, Feb. & Dec, 1887, | 3 | 558 |
| COCHETEUX & CO., Dyers, Roubaix, France | April, 1887, | 1 | 193 |
| DUBOIS & CHARVET-COLUMBIER, Armentières, France | 2 orders, Feb. & Aug., 1885, | 4 | 476 |
| J. LAUREAU, Dyer, Paris, France | Aug., 1885, | 1 | 25 |
| ELMER FRÈRES, Lyons, France | 2 orders, Jan. & June, 1886, | 2 | 208 |
| WALLERAUD, WIART, WATRAMEZ, JACQZ ET CIE., Cambrai, France | June, 1886, | 2 | 416 |
| SUCCESORES DE FRANCISCO ROURA, Farrasa, Spain | Jan., 1886, | 1 | 30 |
| PIETRO ANGELO BOGGIO, Dyer, Strona, Biella, Italy | Feb., 1887, | 1 | 45 |

## BRICK, POTTERY, ETC.

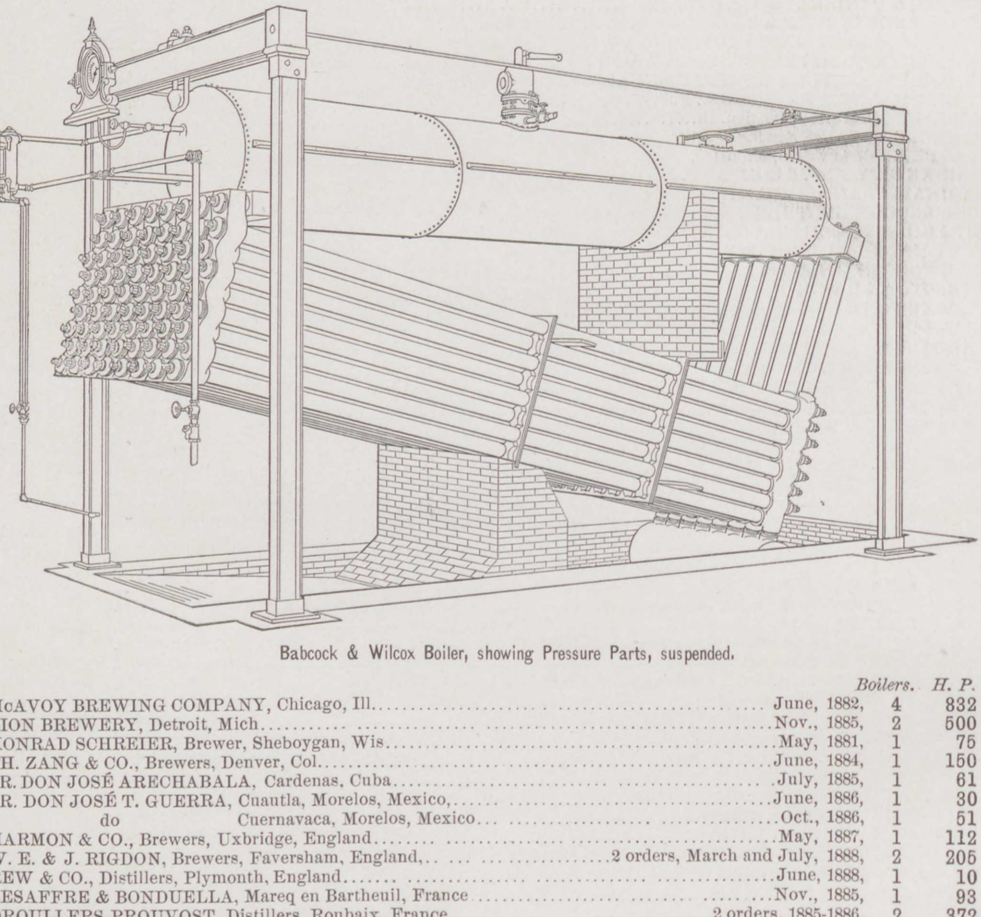
| | | Boilers. | H. P. |
|---|---|---|---|
| JOHN MOSES, Pottery, Trenton, N. J | Aug., 1880, | 2 | 150 |
| HENRY MAURER & SON, Fire Brick, Maurers, N. J | Apr., 1888, | 2 | 244 |
| COPLAY CLEMENT COMPANY, Coplay, Pa | Mar., 1884, | 1 | 104 |
| WOODLAND FIRE BRICK COMPANY (L'd), Woodland, Pa | Aug., 1884, | 1 | 92 |
| YOUNG & FARRELL DIAMOND STONE SAWING CO., Chicago, Ill | 3 orders, 1882-1886, | 3 | 248 |
| ANTHONY SHAW, SON & PAMPHILON, Mersey Pottery, Burslem, Staffordshire, England | Oct., 1888, | 1 | 156 |
| SOCIÉTÉ DES CIMENTS FRANÇAIS ET DES PORTLAND, Boulogne-Sur-Mer, France | Dec., 1887, | 4 | 612 |

## CAR AND WAGON MANUFACTURERS.

| | | Boilers. | H. P. |
|---|---|---|---|
| H. D. SMITH & CO., Carriages, Plantville, Conn | Oct., 1881, | 1 | 75 |
| CORTLAND WAGON COMPANY, Cortland, N. Y. | 2 orders, 1881-1888, | 2 | 186 |
| LEHIGH CAR WHEEL & AXLE COMPANY, Catasauqua, Pa | Dec., 1881, | 2 | 256 |
| ERIE CAR WORKS, LIMITED, Erie, Pa | Sept., 1882, | 1 | 120 |
| PETERS DASH COMPANY, Columbus, Ohio | Sept., 1881, | 1 | 50 |
| COLUMBUS BUGGY COMPANY, Columbus, Ohio | 4 orders, 1882-1887, | 7 | 827 |
| LAFAYETTE CAR WORKS, Lafayette, Ind | Jan., 1883, | 2 | 250 |
| STUDEBAKER BROTHERS MANUFACTURING COMPANY, South Bend., Ind | 4 orders, 1872-1884, | 10 | 1080 |
| do do Chicago, Ill | 5 do Oct., 1885, | 4 | 400 |
| PULLMAN PALACE CAR COMPANY, Pullman, Ill | Sept., 1881, | 8 | 1000 |
| RACINE WAGON & CARRIAGE COMPANY, Racine, Wis | Aug., 1882, | 1 | 125 |
| JAS. L. CLARKE & SON, Carriages, Oshkosh, Wis | May, 1881, | 1 | 107 |
| GOVERNMENT RAILWAY SHOPS, Dunedin, New Zealand | Dec., 1878, | 4 | 200 |
| do do Christ Church, do | Jan., 1879, | 3 | 175 |

## DISTILLERS AND BREWERS.

| | | Boilers. | H. P. |
|---|---|---|---|
| FREDERICK A. POTH BREWING COMPANY, Philadelphia, Pa | Sept., 1883, | 4 | 416 |
| HANNIS DISTILLING COMPANY, Baltimore, Md | 2 orders, 1880-1886, | 3 | 420 |
| BARTHOLOMÆ & LEICHT BREWING CO., Chicago, Ill | 2 do 1881-1888, | 4 | 324 |

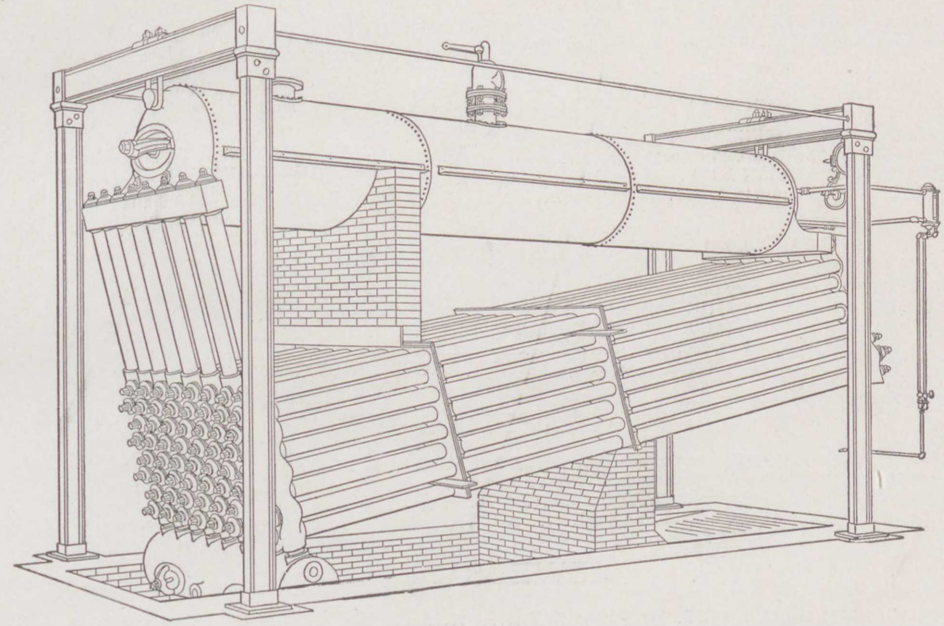


Babcock & Wilcox Boiler, showing Pressure Parts, suspended.

| | | Boilers. | H. P. |
|---|---|---|---|
| McAVOY BREWING COMPANY, Chicago, Ill | June, 1882, | 4 | 832 |
| LION BREWERY, Detroit, Mich | Nov., 1885, | 2 | 500 |
| KONRAD SCHREIER, Brewer, Sheboygan, Wis | May, 1881, | 1 | 75 |
| PH. ZANG & CO., Brewers, Denver, Col | June, 1884, | 1 | 150 |
| SR. DON JOSÉ ARECHABALA, Cardenas, Cuba | July, 1885, | 1 | 61 |
| SR. DON JOSÉ T. GUERRA, Cuautla, Morelos, Mexico, | June, 1886, | 1 | 30 |
| do Cuernavaca, Morelos, Mexico | Oct., 1886, | 1 | 51 |
| HARMON & CO., Brewers, Uxbridge, England | May, 1887, | 1 | 112 |
| W. E. & J. RIGDON, Brewers, Faversham, England, | 2 orders, March and July, 1888, | 2 | 205 |
| REW & CO., Distillers, Plymonth, England | June, 1888, | 1 | 10 |
| LESAFFRE & BONDUELLA, Marcq en Bartheuil, France | Nov., 1885, | 1 | 93 |
| DROULLERS-PROUVOST, Distillers, Roubaix, France | 2 orders, 1885-1886, | 2 | 372 |
| SOCIÉTÉ ANONYME LA GALLIA, Paris, France | May, 1886, | 1 | 51 |
| A. & B. VAGNIEZ, Distillers, Amiens, France | 2 orders, 1885-1886, | 3 | 417 |
| SCHMERZ-FRITSCH, Brewers, Orleans, France | Oct., 1886, | 1 | 40 |
| G. RINCK, Brewer, St. Etienne, France | June, 1887, | 1 | 25 |
| M. M. MOSER ET FILS, Brewers, St. Etienne, Loire, France | Oct., 1888, | 1 | 45 |
| MOËT & CHANDON, Champagnes, Epernay, France | Aug., 1888, | 3 | 240 |
| J. SCHAARSCHUH, Rummelsburg, Germany | Mar., 1887, | 1 | 93 |
| WILHELMSTE BREWERY, Stralan, Germany | May, 1887, | 1 | 93 |
| W. M. FOSTER, Melbourne, Australia | 2 orders, 1887-1888, | 2 | 190 |

## GRAIN AND FLOUR.

| | | Boilers. | H. P. |
|---|---|---|---|
| PIONEER MILLS, Cooperstown, N. Y. | Aug., 1878, | 2 | 150 |
| THORNTON & CHESTER, Buffalo, New York | Nov., 1881, | 1 | 108 |
| ERIE ELEVATOR, Jersey City, N. J. | Aug., 1879, | 4 | 500 |
| H. K. CUMMINGS & CO., Philadelphia, Pa. | July, 1880, | 1 | 104 |
| J. C. KLAUDER, Philadelphia, Pa. | April, 1882, | 1 | 50 |
| McGREW, PARKISON & CO., Monangahela City, Pa. | Jan., 1883, | 1 | 61 |
| H. JULIUS KLINGLER & CO., Butler, Pa. | Aug., 1883, | 1 | 92 |
| WM. LEE & SONS COMPANY, Wilmington, Del. | 2 orders, 1881-1883, | 3 | 275 |
| A. H. SIBLEY, Baltimore, Md. | 2 do 1882-1887, | 2 | 250 |
| KENNESAW MILLS, Marietta, Ga. | May, 1881, | 2 | 200 |
| LANIER MILL COMPANY, Nashville, Tenn. | July, 1881, | 2 | 120 |
| MEMPHIS MILL COMPANY, Memphis, Tenn. | Feb., 1886, | 2 | 164 |
| VALLEY CITY MILLING COMPANY, Grand Rapids, Mich. | Jan., 1885, | 1 | 122 |
| VOIGT MILLING COMPANY, Grand Rapids, Mich. | 2 orders, 1886-1887, | 2 | 280 |
| GEO. P. PLANT MILLING COMPANY, St. Louis, Mo. | 2 do 1883-1887, | 4 | 708 |
| GENESEE MILL COMPANY, San Francisco, Cal. | April, 1882, | 1 | 136 |
| DEMING-PALMER MILLING COMPANY, San Francisco, Cal. | Dec., 1883, | 1 | 208 |
| ALBAITERO & ARRACHE, Macaroni, City of Mexico, Mexico | Aug., 1886, | 2 | 184 |
| BONIFACIO LEYCEGUI, Silao, Mexico | Oct., 1880, | 1 | 60 |



Babcock & Wilcox Boiler, showing Pressure Parts, suspended.

| | | Boilers. | H. P. |
|---|---|---|---|
| MANSON & CO., Aberdeen, Scotland | Jan., 1887, | 1 | 104 |
| W. & P. R. ODLUM, Corn Millers, Port Arlington, Ireland | June, 1884, | 1 | 104 |
| WM. HUGHES, Shrewsbury, England | Jan., 1885, | 1 | 61 |
| RICHARD SHEPPARD, Newchurch, England | Jan., 1885, | 1 | 40 |
| MITCHELL BROS., Whitefoot, England | Oct., 1885, | 2 | 248 |
| BANQUE DE PARIS ET DES PAYS-BAS, Paris, France | Mar., 1886, | 1 | 240 |
| M. FENET, Goussainville, France | July, 1886, | 1 | 61 |
| A. REYNAUD, Marseilles, France | July, 1887, | 1 | 35 |
| LOUIS CARRIE, Marseilles, France | Oct., 1887, | 1 | 51 |
| JOSÉ SORT, Lerida, Spain | May, 1885, | 1 | 25 |
| MICH'L VERDERAME, Paste for Macaroni, Licata, Sicily | 2 orders, 1886-1887, | 2 | 208 |
| AKMET HUSIANOFF, Orenburg, Russia | April, 1886, | 1 | 73 |

## PACKERS AND CANNERS.

| | | Boilers. | H. P. |
|---|---|---|---|
| THE UNION STOCK YARDS COMPANY, Sioux City, Iowa | Sept., 1887, | 4 | 548 |
| MARSHALL CANNING COMPANY, Marshalltown, Ia. | Nov., 1880, | 2 | 120 |
| ARMOUR PACKING COMPANY, Kansas City, Mo. | 2 orders, 1886, | 2 | 500 |
| SILLITOE & SEARES, Packers & Shippers, Manchester, England | Aug., 1885, | 1 | 65 |
| W. STEVENSON, Packer, Manchester, England | Oct., 1885, | 1 | 85 |
| THE BRAZILIAN EX'T OF MEAT & HIDES FACTORY, L'M'D, Paredas, Porte Alegre, Brazil | Sept., 1880, | 2 | 124 |

## WATER WORKS.

| | | Boilers. | H. P. |
|---|---|---|---|
| WESTERLY WATER WORKS, Westerly, R. I | July, 1886, | 2 | 90 |
| PERTH AMBOY WATER COMPANY, Perth Amboy, N. J | Aug., 1881, | 2 | 130 |
| PENNSYLVANIA RAILROAD COMPANY, Philadelphia, Pa | Sept., 1882, | 1 | 60 |
| LACKAWANNA IRON & COAL COMPANY, Water Works, Scranton, Pa | 2 orders, 1883-1887, | 3 | 312 |
| LANCASTER WATER WORKS, Lancaster, Pa | Oct., 1887, | 4 | 416 |
| GREENSBORO WATER WORKS, Greensboro, N. C. | Feb., 1888, | 1 | 45 |
| ELYTON LAND COMPANY, Birmingham, Ala | 2 orders, 1881-1882, | 2 | 152 |
| BESSEMER LAND & IMPROVEMENT CO., Bessemer, Ala | Jan., 1888, | 2 | 90 |
| CENTRAL KENTUCKY LUNATIC ASYLUM, Anchorage, Ky | Nov., 1879, | 1 | 110 |
| JOLIET WATER WORKS, Joliet, Ill | 2 orders, 1881-1882, | 3 | 132 |
| CARTHAGE WATER WORKS COMPANY, Carthage, Mo. | Sept., 1881, | 2 | 120 |
| RED OAK WATER WORKS, Red Oak, Iowa | Aug., 1883, | 1 | 61 |
| PASADENA LAND & WATER COMPANY, Pasadena, Cal | Oct., 1882, | 1 | 43 |
| VISITACION WATER COMPANY, San Francisco, Cal | 2 orders, 1883-1885, | 2 | 101 |
| SPRING VALLEY WATER WORKS, San Francisco, Cal | Mar., 1886, | 1 | 136 |
| MEXBROUGH WATER WORKS, York, England | May, 1886, | 2 | 30 |
| BOURNEMOUTH WATER WORKS, Bournemouth, England | 2 orders, 1886-1887, | 2 | 193 |
| KENT WATER WORKS, Wilmington, England | Mar., 1886, | 4 | 320 |
| WEST SURREY WATER WORKS, Walton-on-Thames, England | Mar., 1887, | 2 | 168 |
| EAST LONDON WATER WORKS COMPANY, Waltham Abbey, England | 2 orders, April and Aug., 1887, | 4 | 372 |
| SOUTHWARK & VAUXHALL WATER WORKS COMPANY, London, Eng | Mar., 1887, | 4 | 336 |
| PIMLICO WATER WORKS, London, England | Nov., 1887, | 1 | 108 |
| IMPRESA CONCESIONARIA DE AGUAS SUBTERRANEAS DEL LLOBREGAT, Barcelona, Spain | 1888, | 2 | 122 |
| PERNAMBUCO WATER WORKS, Pernambuco, Brazil | June, 1885, | 3 | 222 |

## COFFEE, SPICES, Etc.

| | | Boilers. | H. P. |
|---|---|---|---|
| ARBUCKLE BROS. COFFEE COMPANY, Brooklyn, N. Y | 2 orders, 1883-1886, | 4 | 416 |
| ARBUCKLES & CO., Spices, Pittsburgh, Pa | Mar., 1883, | 2 | 102 |
| TWITCHELL, CHAMPLIN & CO., Grocers, Portland, Me | May, 1883, | 2 | 102 |
| CADBURY & CO., Chocolate, Bournville, England | 2 orders, Mar. and July, 1887, | 2 | 186 |

## TOBACCO AND SNUFF.

| | | Boilers. | H. P. |
|---|---|---|---|
| P. LORILLARD & CO., Jersey City, N. J | 3 orders, 1881-1883, | 10 | 1470 |
| GEO. W. HELME COMPANY, Helmetta, N. J | 2 do 1883-1884, | 2 | 122 |
| WILSON & McCALLAY TOBACCO COMPANY, Middletown, O | 2 do 1881-1885, | 2 | 250 |
| G. W. GAIL & AXE, Baltimore, Md | July, 1888, | 2 | 244 |
| WM. CLARK & SON, London, England | 3 orders, 1884-1887, | 3 | 181 |

## ARTIFICIAL ICE.

| | | Boilers. | H. P. |
|---|---|---|---|
| SOUTHERN ICE COMPANY, New Orleans, La | Sept., 1882, | 2 | 272 |
| TEXARKANA ICE COMPANY, Texarkana, Texas | Mar., 1884, | 1 | 30 |
| BATH PURE ICE CO., LIMITED, Bath, England | Mar., 1886, | 1 | 30 |
| L. STERNE & CO., LIMITED, London, England | 3 orders, 1887-1888, | 3 | 205 |

## JEWELRY, Etc.

| | | Boilers. | H. P. |
|---|---|---|---|
| FAHYS WATCH CASE COMPANY, Sag Harbor, N. Y | Apr., 1887, | 2 | 146 |
| KERMENTZ & CO., Jewelry, Newark, N. J | Aug., 1884, | 1 | 50 |
| SOCIÉTÉ GÉNÉRAL DES MONTEURS DE BOITES D'OR, Besancon, France | Sept., 1888, | 1 | 35 |

## MINING.

| | | Boilers. | H. P. |
|---|---|---|---|
| BIGELOW BLUE STONE WORKS, Maiden Lane, N. Y | Jan., 1883, | 1 | 122 |
| NEW JERSEY IRON MINING COMPANY, Port Oram, N. J | Sept., 1886, | 2 | 150 |
| J. C. HAYDON & CO., Janesville, Pa | Jan., 1883, | 1 | 61 |
| LEHIGH COAL & NAVIGATION COMPANY, Lansford, Pa | 1st order, June, 1886, | 14 | 1456 |
| do do Nesquehoning, Pa | 4th do June, 1888, | | |
| J. LANGDON & CO, Incorporated, Shamokin, Pa | Mar., 1887, | 2 | 208 |
| MINERAL RAILROAD & MINING COMPANY, Shamokin, Pa | 2 orders, 1887-1888, | 6 | 720 |
| NEW HOOVER HILL GOLD MINING COMPANY, Randolph Co., N. C | April, 1881, | 1 | 51 |
| N. C. GOLD MINING & REDUCTION COMPANY, Salisbury, N. C | Aug., 1882, | 2 | 100 |
| WM. A. SWEET, Catawba, N. C | Sept., 1880, | 1 | 75 |
| CONGLOMERATE MINING COMPANY, Eagle Harbor, Mich | 5 orders, 1881-1883, | 12 | 1974 |
| SILVER CLIFF MINING COMPANY, Colorado | 2 do 1879-1880, | 4 | 400 |
| GOOD ENOUGH MINING COMPANY, Colorado | Mar., 1880, | 1 | 100 |
| PLATA VERDE SILVER MINING COMPANY, Colorado | Nov., 1879, | 2 | 200 |
| H. L. BRIDGEMAN, Assayer, Pueblo, Colorado | May, 1880, | 1 | 60 |
| RANDOLPH & CO., Central City, Colorado | May, 1881, | 1 | 53 |
| IRON SILVER MINING COMPANY, Leadville, Colorado. | May, 1882, | 3 | 225 |
| MOULTON MINING COMPANY, Butte City, Montana | 3 orders, 1880-1881, | 5 | 375 |
| ALTA MONTANA COMPANY, Wycks, Montana | April, 1881, | 2 | 150 |
| LEGAL TENDER MINING COMPANY Clancy, Montana | April, 1881, | 1 | 75 |

| | | Boilers. | H. P. |
|---|---|---|---|
| NATIONAL MINING & EXPLORING COMPANY, Helena, Montana | May, 1876, | 1 | 75 |
| BIG LODE MINING COMPANY, Idaho | Feb., 1883, | 1 | 82 |
| GERMANIA LEAD WORKS, Salt Lake City, Utah | May, 1882, | 2 | 166 |
| EMPIRE MINING COMPANY, Park City, Utah | 3 orders, 1879-1880, | 8 | 600 |
| ONTARIO SILVER MINING COMPANY, Park City, Utah | 2 orders, Jan. and Aug. 1880, | 3 | 270 |
| MINERAL POINT TUNNEL COMPANY, Utah | 2 orders, 1878-1879, | 2 | 60 |
| HORN SILVER MINING COMPANY, Utah | Nov., 1879, | 2 | 120 |
| G. BILLING, Smelting Works, Socorro, N. M | April, 1883, | 2 | 102 |
| ESTACA DE GUADALUPE DE LOS REYES, Mexico | 2 orders, 1878-1880, | 4 | 245 |
| NEW YORK & CHIHUAHUA MINING COMPANY, Mexico | Mar., 1880, | 3 | 195 |
| CORRALITOS MINING COMPANY, Chihuaha, Mexico | Jan., 1881, | 1 | 50 |
| GUERRA GOLD & SILVER MINING COMPANY, Mazatlan, Mexico | June, 1885, | 1 | 50 |
| CANDELERIA PUMPING SYNDICATE OF NEW YORK, Soledad, Mexico | Feb., 1885, | 2 | 146 |
| NEGOCIACION MÍNERA INTERNACIONAL, Canitas, Mexico | Nov., 1885, | 1 | 61 |
| UNION CATORCINA MINING COMPANY, San Luis de Potosi, Mexico | Sept., 1873, | 2 | 100 |
| VALLECILLO MINING COMPANY, Mexico | Sept., 1881, | 1 | 50 |
| THE ACADIA COAL COMPANY, Stellarton, N. S | 3 orders, 1884-1888, | 5 | 708 |
| BENT COLLIERY, Bothwell, Scotland | 1 do May, 1883. | 4 | 480 |
| do Hamilton, do | 3 do Dec., 1884, | | |
| MARK HURLL, Coal Master, High Blantyre, Scotland | Nov., 1883, | 2 | 240 |
| THE LANEMARK COAL COMPANY, New Cunnock, Scotland | April, 1886, | 2 | 240 |
| COMPAÑIA "LA CRUZ," Linares, Spain | Dec., 1886, | 2 | 95 |
| CHILETE MINING COMPANY, Callao, Peru, S. A. | Dec., 1874, | 3 | 150 |
| GIANT'S DEN MINING COMPANY, Australia | Oct., 1883, | 1 | 73 |
| M. KENNEDY, Colliery, Greymouth, New Zealand | Oct., 1887, | 2 | 248 |

## EXPORT AND COMMISSION HOUSES.

| | | Boilers. | H. P. |
|---|---|---|---|
| WALTON W. EVANS, Civil Engineer, New York | 2 orders, 1871-1878, | 11 | 540 |
| JOSEPH E. SPINNEY, Merchant, New York | Dec., 1878, | 5 | 360 |
| CAMACHO & VENGOECHEA, Merchants, New York | 2 orders, Jan. and Aug., 1880, | 3 | 220 |
| J. FOGERTY, New York | Aug., 1879, | 1 | 75 |
| MOSES TAYLOR & CO., New York | Mar., 1883, | 2 | 146 |
| BECKETT & McDOWELL MANUFACTURING CO., New York | 4 orders, 1880-1883, | 5 | 246 |
| FREDERICK PROBST & CO., Merchants, New York | 5 do 1878-1887, | 9 | 571 |
| HENRY J. DAVISON, New York | 2 do 1882-1884, | 3 | 243 |
| R. H. ALLEN, Merchant, New York | June, 1881, | 2 | 150 |
| BEHR & STEINER, Merchants, New York | Sept., 1881, | 1 | 50 |
| G. REYNAUD, New York, for Cuba | 4 orders, 1882-1885, | 4 | 367 |
| MOTLEY & STIRLING, Merchants, New York | Mar., 1883, | 1 | 104 |
| A. ARANGO & CO., Merchants, New York | Aug., 1882, | 2 | 208 |
| MAITLAND, PHELPS & CO., New York | 8 orders, 1881-1888, | 9 | 845 |
| J. CRICHTON, Valparaiso, Chili | Jan., 1882, | 1 | 50 |
| COOMBS, CROSBY & EDDY, New York, for Mexico | July, 1881, | 1 | 30 |
| SORZANO & CO., Merchants, New York | 2 orders, 1881-1883, | 3 | 442 |
| FERNANDEZ & CASTILLO, New York | Feb., 1883, | 1 | 104 |
| H. A. VATABLE & SON, New York | Oct., 1882, | 1 | 104 |
| MOSLE BROS., New York, for Cuba | 8 orders, 1883-1886, | 14 | 2440 |
| ROBERT DEELEY & CO., New York | May, 1883, | 4 | 416 |
| E. L. BECERRA'S NEPHEW & CO., New York | Jan., 1884, | 1 | 104 |
| BUTLER, McDONALD & CO., New York | 2 orders, 1884-1885, | 4 | 480 |
| COLWELL IRON WORKS, New York, for Louisiana | 2 do Mar., 1879, | 4 | 400 |
| do do for Mexico | 3d do Aug., 1884, | 1 | 122 |
| J. L. MOTT IRON WORKS, New York, for Mexico | Feb., 1884, | 1 | 15 |
| AUGUSTUS A. GOUBERT, New York, for Cuba | 2 orders, 1884-1885, | 3 | 246 |
| CANDELERIA PUMPING SYNDICATE of N. Y., for Mexico | Feb., 1885, | 2 | 146 |
| M. ECHEVERRIA & CO., New York, for Mexico | Oct., 1885, | 1 | 75 |
| THEO. HERRMANN, New York, for Mexico | Oct., 1885, | 1 | 61 |
| M. CAMACHO ROLDÁN & NEPHEW, New York for Mexico | June, 1887, | 1 | 122 |
| GEO. BRUCE'S SON & CO., New York, for Mexico | 2 orders, Oct. and Dec., 1887, | 2 | 184 |
| J. & G. FOWLER, New York, for Cuba | 2 do Sept. and Dec., 1887, | 4 | 584 |
| HUGH KELLY, New York, for Ceiba Hueca, W. I. | Jan., 1888, | 1 | 208 |
| GOMEZ & PEARSALL, New York, for Cuba | Nov., 1888, | 1 | 73 |
| E. ATKINS & CO., Boston, Mass., for Cuba | Nov., 1888, | 1 | 156 |
| ROBT. McCULLOCH, Yonkers, N. Y., for Cuba | Sept., 1886, | 1 | 104 |
| D. L. HOLDEN, Philadelphia, for China | Sept., 1880, | 1 | 60 |
| J. ARCE & CO., City of Mexico | 2 orders, Mar. and July, 1888, | 2 | 91 |
| JAMES KEITH, Hydrographical Engineer, Edinburgh, Scotland | 9 orders, 1884-1886, | 9 | 295 |
| BLAIR, CAMPBELL & McLEAN, Glasgow, for Costa Rica | Feb., 1887, | 1 | 122 |
| ARTHUR BUTLER, London, for India | 14 orders, 1884-1887, | 14 | 634 |
| JAMES McEWAN & CO., London, for Australia | 2 do 1884-1885, | 10 | 1040 |
| JAMES SIMPSON & CO., LIMITED, Engineers, London, Eng | 5 do 1885 1888, | 12 | 871 |
| WALKER BROS., London, for Ceylon | 11 do 1886-1888, | 12 | 271 |
| J. & H. GWYNNE, London, for China | Sept., 1886, | 2 | 146 |
| ANDERSON BROTHERS, London, for India | Nov., 1886, | 1 | 120 |
| W. WALKER, London, for Batavia | Nov., 1885, | 1 | 13 |
| A. STUART, London, for Batoum, Russia | April, 1886, | 1 | 104 |
| FARMER & BRANDON, Merchants, London, England | Aug., 1888, | 1 | 20 |
| NELSON BROS., London, England, for New Zealand | 2 orders, 1887-1888, | 2 | 140 |
| TAKATA & CO., London, England, for Japan | 2 do 1887-1888, | 4 | 332 |

| | | Boilers. | H. P. |
|---|---|---|---|
| H. F. STANES, London, England, for New Zealand | Jan., 1888, | 1 | 104 |
| HAMMOND & CO., London, England, for Spain | Oct., 1887, | 1 | 104 |
| DU TEMPLE & CO., Liverpool, England, for Asia Minor | July, 1886, | 1 | 82 |
| MILLWARD, BRADBURY & CO., Liverpool, England, for Brazil | 6 orders, 1886-1888, | 7 | 613 |
| E. GRETHER, Manchester, England, for Genoa, Italy | 2 orders, Feb. and Oct., 1887, | 2 | 34 |
| ZIFFER & WALKER, Manchester, England, for Brazil | Dec., 1887, | 2 | 124 |
| EDGAR ALLAN & CO., Sheffield, England, for Spain | June, 1887, | 1 | 30 |
| S. WALKER & CO., Wolverhampton, England, for Hong Kong | Sept., 1883, | 1 | 104 |
| E. R. & F. TURNER, Ipswich, England, for Ceylon | Mar., 1887, | 1 | 20 |
| ASA LEES & CO.. LIMITED, Oldham, England, for Bombay | Feb., 1888, | 3 | 372 |
| JOHN HENRY STEWART, Withington, England, for Brazil | Mar., 1888, | 1 | 62 |
| FISHER & CO., Huddersfield, England, for Canada | Mar., 1888, | 1 | 108 |
| AGAR, CROSS & CO., Glasgow, for Argentine Republic | Oct., 1888, | 1 | 57 |
| LOUIS FONTAINE, La Madeleine, les Lille, France | 44 orders, 1883-1888, | 61 | 9064 |
| AMELIN & RENAUD, Paris, for Buenos Ayres | 2 orders, July and Sept., 1887, | 2 | 50 |
| ALEXANDER B. BARY, Moscow, Russia | 25 orders, 1883-1888, | 29 | 1748 |
| J. S. BERGHEIM, Vienna, Austria, for Oil Wells at Garlice-Galicia | April, 1887, | 2 | 186 |
| JOHN McDONALD, Townsville, N. Q., Australia | Sept., 1887, | 1 | 51 |
| LEMGRUBER & LEMGRUBER, Rio Janeiro, Brazil | May, 1888, | 1 | 40 |
| WALSH, LOVETT & CO., Birmingham, Eng., for the Himalayas | Mar., 1888, | 2 | 107 |

## MISCELLANEOUS.

| | | Boilers. | H. P. |
|---|---|---|---|
| HALLET & DAVIS COMPANY, Pianos, Boston, Mass.<br>do do do do *Moore Boiler Built over*, | 2 orders, 1881-1888, | 2 | 218 |
| HEATON BUTTON FASTENER COMPANY, Providence, R. I | Apr., 1888, | 1 | 92 |
| UNION INDIA RUBBER COMPANY, New York | Mar., 1882, | 2 | 120 |
| E. GREENFIELD'S SON & COMPANY, Confectioners, Brooklyn, N. Y | Feb., 1884, | 2 | 164 |
| MILLER, HALL & HARTWELL, Shirts, Troy, N. Y | Jan., 1883, | 1 | 122 |
| WRIGHT BROTHERS & COMPANY, Umbrellas, Philadelphia, Pa | Dec., 1873, | 1 | 75 |
| NOAH BARLOW, Upholsterers' Goods, Philadelphia, Pa | May, 1884, | 1 | 30 |
| WISE BROTHERS, Overalls, &c., Baltimore, Md. | Feb., 1887, | 2 | 102 |
| VOGLER & GEUDTNER, Trunks, Chicago, Ill | July, 1881, | 1 | 83 |
| R. & J. SALMOND, Bakers and Confectioners, Aberdeen, Scotland | Sept., 1888, | 1 | 40 |
| C. G. ELRICK & COMPANY (L'd), Comb Works, Aberdeen, Scotland | June, 1887, | 1 | 136 |
| CLOG SOLE FIBRE COMPANY, Liverpool, England | Nov., 1885, | 1 | 138 |
| JAMES PATTERSON & COMPANY, Pifeford Mills, Blackley, England | July, 1886, | 1 | 73 |
| BRITISH PNEUMATIC PULVERIZING COMPANY, London, England | 2 orders, 1886-1887, | 2 | 80 |
| THOMAS CARLYLE, Buttons, Birmingham, England | Nov., 1886, | 1 | 51 |
| BASTIN & LAWSON, Southampton, England | Jan., 1887, | 1 | 30 |
| OUTRAM & COMPANY, Preston, England | Feb., 1887, | 2 | 280 |
| C. TATTERSALL, Cotton Broker, Manchester, England | Sept., 1888, | 1 | 75 |
| FELBUR, JUCKER & COMPANY, Manchester, England | Nov., 1888, | 1 | 104 |
| ROBT. CHARLTON & SONS, Calenders, Manchester, England | May, 1887, | 1 | 156 |
| THE COWLES SYNDICATE COMPANY, Limited, Aluminium, Milton, Eng | Oct., 1887, | 2 | 280 |
| W. E. CAMERON, Macclesfield, England | Oct., 1887, | 1 | 30 |
| LANGWORTHY BROTHERS, Grengate Mills, Salford, England | Nov., 1887, | 1 | 173 |
| CAMBRIAN PATENT FUEL COMPANY, Cardiff, Wales | Dec., 1886, | 1 | 92 |
| F. DE LA ROYÈRE-MASURCEL, Rubber Manufacturers, Brussels, Belgium | Aug., 1888, | 1 | 46 |
| M. BAYART, Tourcoing, France | Nov., 1884, | 1 | 240 |
| BINET, PÈRE ET FILS, Tourcoing, France | Jan., 1885, | 1 | 136 |
| EDMOND BERTRAND, Cambrai, France | June, 1885, | 2 | 102 |
| A. DUPONT ET CIE., Brush Manufacturers, Beauvais, France | Feb., 1886, | 1 | 104 |
| CUVIER, Clog-maker, Neuville, Ferrières, France | Nov., 1886, | 1 | 51 |
| ROUSSEL, Wick-maker, Amiens, France | Nov., 1886, | 1 | 20 |
| ANTISSER FILS, Marseilles, France | Dec., 1886, | 1 | 136 |
| HARDING COCKER, Lille, France | Oct., 1887, | 1 | 30 |
| MARCHAND FRÈRES, Dunkirk, France | Oct., 1887, | 1 | 138 |
| LOUIS GLORIEUX, Roubaix, France | Oct., 1887, | 1 | 166 |
| CARRAGIO & TRINXET, Barcelona, Spain | Oct., 1885, | 2 | 146 |
| GARCIA GIRONA Y CIA., Brushmakers, Barcelona, Spain | Dec., 1885, | 1 | 30 |
| PERERA & PORTABELLA, Spain | Feb., 1888, | 1 | 127 |
| H. GUTSCHOW, Pianos, Berlin, Germany | Mar., 1887, | 1 | 35 |
| C. SCHUBERT, Berlin, Germany | April, 1887, | 1 | 30 |
| STEINLEIN BROTHERS, Berlin, Germany | Sept., 1887, | 1 | 51 |
| KOHLSTEDT & GRAMMBERG, Nordeney, Germany | Jan., 1888, | 1 | 25 |
| PFLAUM & GERLACH, Berlin, Germany | July, 1887, | 1 | 26 |
| VOMVILLER & CO., Romagnano, Italy | May, 1885, | 1 | 208 |
| TOSI & CO, Legnana, Italy | Nov., 1886, | 1 | 51 |
| GUISEPPE PINSONI, Genoa, Italy | Mar., 1887, | 2 | 148 |
| MELCHOIORRE BELLETIERI, Civita Vecchia, Italy | June, 1887, | 1 | 30 |
| A. IVANOWITSCH ALEXAJEFF, Moscow, Russia | 2 orders, 1883-1884, | 2 | 195 |
| R. & T. ELWORTHY, Elizabethgrad, Russia | June, 1884, | 1 | 23 |
| S. M. LIANASOFF, Salt Mill, Waldimiroffka, Russia | Feb., 1885, | 1 | 73 |
| S. M. SHIBÆFF & CO., Batoum, Russia | Sept., 1885, | 1 | 51 |
| A. W. MAKAROFF, Wadding Manufacturer, Astrakan, Russia | July, 1886, | 1 | 30 |
| LA COMPAÑIA NOVA INDUSTRA, Rio de Janeiro, Brazil | Oct., 1886, | 1 | 35 |
| JOAQUIN ARANGO, Rio de Janeiro, Brazil | Oct., 1888, | 1 | 35 |
| JUAN LAMAISON, Buenos Ayres, Arg. Rep | Oct., 1886, | 1 | 15 |
| J. P. OWEN, Tea-planter, Maturata, Ceylon | Mar., 1887, | 1 | 20 |

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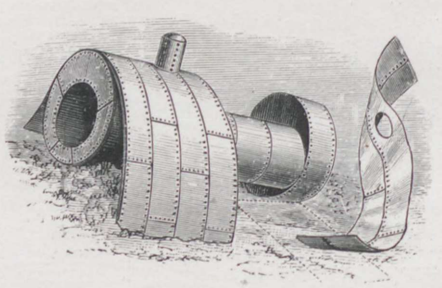

THE END. (OLD STYLE.)