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MILL ARCHITECTURE.*

BY C. JOHN HEXAMER.

The first principle in architecture, and foremost in buildings intended for manufacturing purposes, is utility ; and all other considerations are subservient to it. The elements of Vitruvius—*firmitas, utilitas, venustas*, stability, utility, beauty—still hold good. That mill building is the best which is best suited for its purpose, and that architect is most expert, who exactly knows what changes in his plans are required for every department of manufacture. I, of course, do not mean to say that a mill should be erected in bad proportions “a hideous mass of stone, an eyesore to mankind ;” on the contrary, an architect shows his superior skill if, notwithstanding the small amounts usually allotted to decorative purposes, and the fetters which that tyrant utility places on him, he is still able to erect an evenly proportioned, well-looking building. The higher a building is, the better should be its construction. The simplest of all rules of building, to construct a building safely and solidly, is frequently neglected. The great principle in fire constructions is to divide the building into numerous parts, and then to construct these parts in such a manner and of such a material that a fire originating in any one part may be restricted to it. The main great divisions into which a manufacturing place is divided are the stories.

* A lecture delivered before the Franklin Institute, December 17, 1884.

It becomes our problem then to construct each story so that a fire starting in one, may be restricted to that story; so that smoke, fire and water used to extinguish the flames, may not harm other stories and their contents. To arrive at this result there must be no openings in the floors; that is, the elevators and stairways must be outside of the main building, and belt and other openings must not break the floors. In order to accomplish this we must place stairways and elevators in separate stairway and elevator houses, the walls of which should be of sound brick and of sufficient thickness. The walls should only be broken by the doors leading into the separate stories. These doors should be iron-lined on both sides, and should be self-closing (either by a spring or weight) the doors being held open by a piece of fusible solder, which melts at any considerable rise of temperature.

The practice of putting in wooden sills, and lining them on top with sheet iron, is to be deprecated, as the woodwork of the adjoining floors forms a juncture with the wooden sill, and a fire will be transmitted underneath the iron. The elevator openings in the elevator house should be self-closing, so that a double security—the elevator doors and the doors leading into the main building—may be had. Especial care should be taken to extend the walls of the stairway and elevator house through the roof of the main building, thus cutting the trussing and timbering of the roofs, so that a fire may not be transmitted through the woodwork of the roof. A good-sized ventilator should be placed over the elevator house, so that in case of fire the smoke may escape through this—like a chimney—thus making it easier for firemen to see and work, and for employes to escape from the building; this is of so much importance that the Philadelphia Fire Underwriters' Tariff Association has made it a requirement in hotel buildings. Great care must be taken to keep the bottom of elevator houses free from waste and rubbish as these by igniting either spontaneously, or by a burning object being thrown into them, have caused many fires. The safest construction for a stairway house is that used at the Ontario Mills, of the Arrott Steam Power Mill Company, in which the stairway house is entirely cut off from the main mill by blank coped walls without any direct communication with the mill, the communication between the mill and the stairway house being effected by means of iron porches on the outside of every story.

FLOORS.

The safest floor, which has for a long time been used in fire-proof construction, is one consisting of brick arches, sprung between iron girders. In order to be of practical value, the spans must not be too large, as iron, which is an excellent conductor, soon warps by unequal expansion in case of fire, and is apt to throw out the intervening arches. When spans are large, the intervening arches readily drop out of the girders which hold them, and thus entire buildings, which were considered fire-proof have been totally destroyed. Care must, therefore, be taken to cover all exposed iron surfaces with a poor conductor of heat.

A construction much used in France, which has proved successful in many cases, is an iron girder with concrete arches, the arches being formed by means of moulds and held together with tie rods until dry. When good concrete dries, it becomes as hard as stone, and being an excellent non-conductor of heat, when properly erected, so as to surround the entire iron work, keeps the iron from becoming heated and and warping.

Iron girders have also been used in conjunction with terra cotta, and with the so-called terra cotta lumber. Terra cotta lumber is a material manufactured from clay and saw-dust. The clay mixed with saw-dust, is formed into the required shape, then dried, and burned in a kiln; the organic part is destroyed, and a porous mass remains which may be worked with a chisel like lumber. Tests which have been made with this material in New York have proved very satisfactory.

[A number of slides were then shown, illustrating the manner in which these different materials are used and erected.]

A concrete floor, when made with good cement, is, next to a brick arched floor, the best known. This substance forms into one solid, hard, rock-like mass, and those who have seen the works in France, where entire churches and aqueducts have been built with it, can no longer doubt its efficiency. It may be well remembered how at the great fire of the Jayne building, in Philadelphia, an ordinary mortar floor saved the second story. The problem then is, "How can we construct a cheap, light and effectual floor?"

A solid three-inch plank floor, laid flat, tongued and grooved, with one and a quarter inch flooring boards on top arranged for flooding, is

REPORT ON STEAM BOILERS.

U. S. S. Tennessee, NEW ORLEANS, LA.

February 13, 1885.

To the Chairman of the Board of Examiners on Steam Boilers.

GENTLEMEN :—Enclosed I send you a copy of the results of tests made during the late International Electrical Exhibition, together with an account of the methods used, and the deductions from the results.

The drawings of all the boilers are in the possession of Professor Marks, and I would recommend that they be reproduced for the report. I have not that data with me which can be taken directly from the drawings, and have left blanks wherever, in the description of the boilers, data should be filled in.

The thanks of the Committee are due to the Crosby Steam Gauge and Valve Company, for the use of their standard steam gauges and test pumps; also to Mr. M. B. Edson for his recording and alarm gauge, which was used in each of the tests; also to the Blake Manufacturing Company, for the use of two pumps for feeding boilers during the tests; and to Riehlé Brothers and Mr. Troemner for the use of scales during the tests.

The following named young men rendered valuable assistance in observing and recording the data during the tests, and are especially entitled to the thanks of the Committee.

Geo. R. Green,	H. Szlapka,	Leon Kraft,
Charles H. Small,	F. Thibault,	Richard McCall,
George K. Fischer,	E. E. Alcott,	R. L. Rutter,
W. F. Lubbe,	Wm. A. Bigler,	D. E. Tracy,
L. F. Roudinella,	Theodore Gould, Jr.,	Joseph Israel,
	Thos. Grier.	

All the calculations have been checked at different times by different computers.

Hoping the results and methods have been satisfactory to the Committee,

I am, very truly yours,

H. W. SPANGLER (*for Section X*),
Assistant Engineer, U. S. Navy.

Code of the Proposed Quantitative Tests for the Evaporative Efficiency of Boilers at the International Electrical Exhibition, by the Franklin Institute, of 1884.

SPECIAL NOTICE.

Boilers may be exhibited and used at the International Electrical Exhibition, but will not have quantitative tests made of their efficiency unless formal application is made, and the subjoined code accepted before July 15, 1884.

Competitive tests will not be made unless at the joint request of the

parties desiring a competitive test, and after they have agreed to and subscribed to this code, and fixed upon a rating for the points enumerated in Article 4.

The Committee of judges reserve the right to limit the number of tests made, should time and opportunity not permit all the tests desired to be completed.

SECTION I.—PRELIMINARIES TO THE TESTS.

ARTICLE 1. (Capacity.) The boilers entered may be of any capacity having an evaporative power, not less than seven hundred and fifty pounds of water per hour.

Each boiler must be so drilled as to enable its whole internal capacity to be determined by being completely filled and emptied of water. Proper cocks, piping, etc., must be so placed as to enable this to be done readily.

ART. 2. (Pipes and Valves.) Each exhibitor will furnish all the pipes and valves necessary to make connection with the main water and steam pipes in a proper manner, and subject to the orders of the Superintendent. He will also make any alterations in water and steam pipes required for the tests, furnishing all tools, piping, cocks, and mechanical labor at his own cost.

ART. 3. (Space.) Each exhibitor will be furnished with space at the regular rates established for the exhibition, in which space he must build his foundations and boiler setting, and make connection with the chimney flue, if required, at his own cost, and subject to the approval of the Superintendent.

ART. 4. (Specifications.) Each exhibitor must furnish to the Chairman of the committee of judges on steam boilers, such description and drawing, both of the boiler in position and of the details of the boiler, as will facilitate the labor of that committee, together with his claims as to meritorious points for his exhibit.

The following points will have special consideration :

1. Economy of fuel.
2. Economy of material and labor of Construction.
3. Evaporative power. (Space occupied.)
4. Simplicity and accessibility of parts.
5. Durability of whole structure.

Exhibitors desiring a competitive test made, must agree upon a rating for these points before it will be made.

Exhibitors must also file the following data :

Area of heating surface to the nearest hundredth of a foot.

Area of grate surface to the nearest hundredth of a foot.

Area of calorimeter to the nearest hundredth of a foot.

Area of chimney flue to the nearest hundredth of a foot.

Height of chimney required.

Number of pounds of coal per square foot of grate to be burned per hour.

Should the calculations of the committee of judges differ in result from

those of the exhibitor, he will be required to give all the details of his calculations, and an agreement must be reached before proceeding with the test.

SECTION II.—PREPARATIONS FOR THE TESTS.

ART. 5. (Coal). Anthracite coal will be used and will be furnished free of charge, provided the steam made is used for the general purposes of the Exhibition.

The same quality and size of coal will be used in all the tests, unless special arrangements be made for another kind of fuel.

An analysis will be made of the coal used. The coal will be weighed to the boiler.

ART. 6. (Water). The water used will be taken from the city mains. The feed water for the boilers will be weighed by means of scales and a large tank, and will be run into a smaller supplemental tank, from which it will be pumped into the boiler by means of a feed pump actuated by steam from the boilers.

The temperature of the feed water will be taken by means of a standard thermometer, in the supplemental tank.

ART. 7. (Pressure.) The steam pressure used shall not exceed ninety pounds per square inch by the guage, unless by special arrangement with the committee of judges.

A standard guage will be used and also a standard thermometer immersed in a mercury pocket in the steam space.

ART. 8. (Safety Valve.) The safety valve will be set to blow off at ten pounds above the pressure fixed upon.

ART. 9. (Leaks.) Within twenty-four hours preceding the test of a boiler, it must be subjected to hydraulic pressure, ten pounds greater than its steam pressure during the test, and proved to be perfectly tight.

ART. 10. (Attendants.) The attendants in charge of the boiler tested must be approved by the party whose boiler is tested and by the judges. All attendants are to be subject to the orders of the judges during the progress of the test.

ART. 11. (Ashes.) All ashes will be weighed on being withdrawn from the ash pit, and must not be damped until weighed.

ART. 12. (Calorimeters.) The calorimeters used will consist of a barrel, scale and hand thermometer. Two calorimeters will be used and simultaneous observations made at fifteen minute intervals.

ART. 13. (Fires.) The exhibitor shall be allowed one day previous to the test to clean boilers and grates.

The steam having reached the required pressure, the ash pit shall be thoroughly cleaned and swept, and thereafter the fire maintained as nearly uniform as possible, the test closing with the same depth and intensity of fire as it opened.

This point is to be decided by the judges who may make allowance if it be clearly shown to have been impossible to maintain uniform fires.

If in the judgment of the committee of judges the firing is inefficiently or improperly done, the test may be terminated at any time, and a repetition of the test refused.

ART. 14. (Pyrometer.) The temperature of the gases of combustion immediately upon entering the chimney flue shall be taken by means of a suitable pyrometer, read at fifteen minutes intervals, and close to the boiler.

ART. 15. (Manometer and Barometer.) The vacuum in the chimney flue shall be taken by means of a water manometer read at fifteen minutes interval. A barometer will be read simultaneously.

ART. 16. (Duration.) Unless otherwise arranged, the tests will last ten hours.

ART. 17. (Economy and Efficiency of the Boiler.) The level of the water in the boiler and the state of the fire must be kept as nearly constant as possible during the whole of the trial.

The weight of the water in the boiler for each one quarter of an inch, on the glass water gauge, will be carefully determined and recorded previous to the test, and proper correction for unavoidable changes of level made.

The weight of water fed to the boiler, subject to proper corrections, will be multiplied by its observed thermal value as steam. From this product the thermal units of heat brought in by the feed will be subtracted.

The remainder will be divided by nine hundred and sixty-six and seven-hundredths British thermal units, giving the number of pounds of water evaporated from and at two hundred and twelve degrees Fahrenheit.

This latter quantity will be divided by the weight of coal burned, less weight of dry ashes, giving the number of pounds of water evaporated per pound of combustible. This shall be taken as the measure of the efficiency of the boiler.

The nominal horse-power of the boiler will be deduced by dividing the number of pounds of water evaporated from, and at two hundred and twelve degrees Fahrenheit per hour by thirty.

The evaporative power of the boiler will be determined by dividing the normal horse-power of the boiler by the number of cubic feet of space it occupies.

The space occupied by a boiler and its appurtenances will be regarded as the product of the square feet of floor space occupied by its extreme height in feet.

METHODS USED IN TESTING BOILERS.

All the boilers tested by this committee were located in a boiler-house to the north of the exhibition building proper, this boiler-house being open to the weather on the sides. It is probable that the boilers would have shown a higher efficiency, had the boiler-house been entirely enclosed, as the weather was quite cold during part of the tests.

The methods used were, as nearly as possible, the same for each boiler, and are given in detail below.

WATER.

All the water fed to the boilers during the tests was taken from two large tanks, each holding about 2,400 pounds of water, when full. In starting each test, the water-level in the boiler was noted, and all water put into the boiler after the test began was taken from the above-mentioned tanks which were alternately weighed and emptied. At the end of a test, the water-level in the boiler was brought to the same point as at starting, and the amount of water left in the tanks weighed and properly accounted for.

The steam pumps used on all the boiler tests worked very satisfactorily, there being no leaks about either pumps or pipes.

Before testing a boiler, a joint on each water pipe leading to the boiler was broken, and all the pipes disconnected excepting the one feeding from the pump used in testing.

SCALES.

The scales used for weighing feed water and coal were of Riehlé's make, and those used for the calorimeters were partly of Fairbank's and partly of Riehlé's make. All the scales were very accurate and were checked by comparison with Fairbank's standard weights of 50 pounds each.

TEMPERATURE OF FEED WATER.

The temperature of all water fed to the boilers was taken at intervals during the tests, and the mean of these temperatures was taken as the temperature of the feed. The thermometers used were made by J. & H. J. Green, of New York, and were very accurate.

COAL.

The coal used in these tests was purchased at different times and the size was as desired by the exhibitors of the various boilers. All coal was weighed in barrows and allowance made for all that was not used. The coal in all the tests was as it came from the dealer and was slightly wet. In each test a number of barrows full of coal were dried at the temperature of the air, and again weighed, but no appreciable loss of weight was perceptible. In the test of the Root boiler, the floor under the coal was constantly wet from water from the calorimeters used, but the greater part of the coal used was in the same condition as that used in the other tests.

A careful analysis of the coal was made under the direction of Professor Samuel P. Sadtler, from samples taken, from time to time, during the test by Mr. Spangler.

WOOD.

The wood used was such as happened to be most convenient, and was not all of the same kind, but the amount used was so small in comparison with the total amount of fuel, that the same allowance was made in each case for the relative values of coal and wood.

ASHES.

All ashes were weighed dry, and at the end of the test the fire was drawn, and where any unburnt coal came from the furnace, it was credited to the coal account, the remainder was charged to the ash account.

In the case of the Dickson boiler, the ashes were very wet as they were drawn from the ash pan, as the steam blower discharged directly into the ash pan. A number of barrows of ashes were weighed and the percentage of moisture was calculated from the weight after drying, and due allowance made for the same in the ash account.

BAROMETER.

The readings of the barometer were taken from the observations made by the United States Signal Service in Philadelphia, during the time of the tests.

THERMOMETER.

The temperature of the air was taken from the same source and agreed very closely with that taken during the tests.

STEAM PRESSURE.

The steam gauge used on the tests was furnished by the Crosby Steam Gauge and Valve Company. One of these gauges was tested by Thomas Shaw, of Philadelphia, with a mercury column for every five pounds from 0 to 120 pounds, both ascending and descending.

Before and after each test the gauge used on the boilers was carefully compared with this standard, both ascending and descending throughout the range of pressure used on the tests. The gauges were very accurate and agreed as well at the end as at the beginning of the set of tests. Readings were taken at frequent intervals, and the mean of these readings taken as the mean pressure of the steam.

In addition to the Crosby gauge used, an Edson Recording Gauge was attached to each boiler as it was tested, and records made during the entire test. The indications of this gauge were accurate and reliable, but the clockwork required frequent adjusting to keep the recording slip moving at a uniform speed. The alarm attached to the gauge was not used.

TEMPERATURE OF THE STEAM.

A large monitor thermometer was used for indicating the temperature of the steam. It was screwed into the steam space of the boiler, and its indications noted from time to time. These thermometers were a little slow in acting, as there was a considerable body of iron and mercury to change in temperature, but the indications are considered very reliable.

TEMPERATURE OF SMOKE-STACK.

In determining this temperature a monitor thermometer was inserted in the smoke-stack, just back of the damper in the Root, Baldwin, and Harrison boiler, and at the bottom of the smoke-pipe in the Dickson boiler. It was not practicable in all cases to put the thermometer in vertically. In the Harrison test it was vertical; in the Dickson test it was inclined at an angle of about 30 degrees to the vertical; and in

the Root and Baldwin tests, the thermometer was inclined about 10 degrees from the horizontal. The bulb of the thermometer was put as near as possible into the centre of the flue, while the stem projected into the air. The openings into the flue around the thermometer were carefully closed so that no air could enter. Readings were taken as often as practicable from these thermometers, and the mean of the readings taken.

DRAFT IN CHIMNEY.

A number of devices were used for measuring the draft in the chimney. That used on the Root boiler was suggested by Professor Lanza, and was the design of Mr. Fisher, of the Massachusetts Institute of Technology. It consisted of two chambers *a* and *b*, Fig. 1, each covered by a rubber diaphragm *c* and *d*. The interior of the

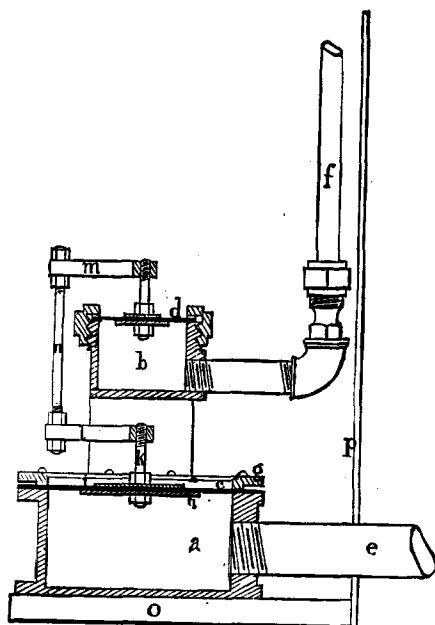


FIG. 1.

chamber *a* is connected with the interior of the chimney by means of a pipe *e*, supplied with a three-way cock so that the interior of *a* can be connected with the chimney or with the air. The interior of *b* is connected by means of a pipe to a vertical glass tube *f*, open at the top.

The chamber *b*, the glass tube *f*, and the connecting pipe are filled with water, the air being entirely excluded. The chamber *b* and all its attachments are carried on the annular ring *g*, which holds the rubber diaphragm of *a* in place. To the centre of the diaphragm *c* two plates *h, h*, are attached which support a vertical rod *k*. This rod screws into a cross-head *l*. To the diaphragm of *b* a similar cross-head *m* is attached in the same way, and these two cross-heads are connected by means of two side rods, only one of which, *n*, is shown. The whole apparatus rests on a base board *o*, which carries a vertical piece *p* to which a paper scale graduated in inches is attached. The method of using the apparatus is as follows: The three way cock in *e* being turned so that *a* is in communication with the air, the reading of the scale opposite the head of the water column is noted. The three-way cock is turned so that the inside of *a* is connected with the chimney, and the reading of the top of the column in *f* is again noted, and the difference between the readings is caused by the difference in pressure inside and outside the chimney. This difference divided by the ratio of the areas of the chambers *a* and *b* is the vacuum in the chimney in inches of water.

Comparison was made between this apparatus and the one referred to as the invention of Professor Webb, and the two methods were found substantially to agree.

As the Webb apparatus was more convenient, the one just described was used only on the Root boiler.

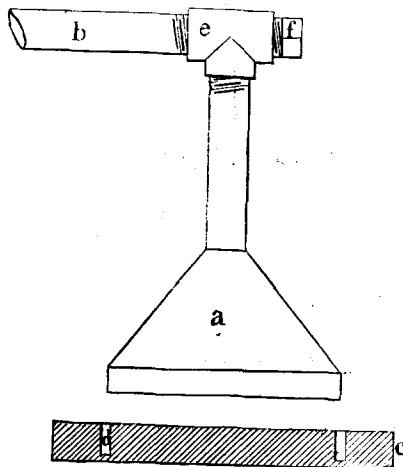


FIG. 2.

In testing the other boilers the following described apparatus, the invention of Professor J. Burkitt Webb, a member of the Committee, was used.

It consisted of an inverted funnel-shaped vessel, *a*, Fig. 2, whose interior is connected through the pipe *b* to the chimney. A piece of gas piping was put into the chimney and connected directly to the pipe *b*. The **T** *e*, had one end closed by a plug, *f*, so that, if desired, the interior of the funnel *a* could be connected to the air. The funnel *a* and pipe *b* were suspended over a board, *c*, having a circular groove, *d*, cut into its upper face. This board rested on a pair of Fairbanks' scales weighing to ounces. The groove *d* was filled with mercury and the edge of *a* dipped into this mercury.

The method of using the apparatus was as follows: The plug *f* being removed, the scales were balanced; the plug was then replaced, and *b* being connected to the chimney, the scales were balanced again and the difference or loss of weight noted. The loss of weight divided by the area of the mouth of *a* is the loss per square inch, and represents the difference in pressure inside and outside the chimney, and this multiplied by 1.728 gives the corresponding draft in inches of water. The apparatus worked very satisfactorily and the results are very reliable.

QUALITY OF STEAM.

One of the most difficult subjects presented to the Committee was the quality of the steam generated, and we do not think the results obtained are to be implicitly trusted. The data was taken as carefully as could be, but the imperfections of the apparatus were such, that it is a matter of much doubt as to how much reliance can be placed on the results.

There were a number of devices presented to the Committee for use and discussed in their meetings, and the three following described were adopted and used in the tests.

It will be noticed that two different methods of testing the quality of the steam from each boiler were employed, except in the case of the Baldwin boiler, and the results vary so much that no conclusions can be drawn as to the degree of accuracy of either.

While it may be considered that the apparatus giving the most regular results is most to be depended upon, I am satisfied that the conditions in the best boiler are such that the quality of the steam must

be very variable, and it is doubtful whether a mean result is a satisfactory one or not.

The entire subject requires much more investigation than your Committee had the time to undertake.

BARREL CALORIMETER.

One apparatus used for testing the quality of the steam was an ordinary barrel resting on Riehle's scales. A quantity of water was put into the barrel and its weight noted. Just before making the experiment, the temperature of the water was noted. A steam pipe from the boiler led down to within a short distance of the barrel and was covered with felting. To the end of this pipe a short length of hose was attached. Everything being ready for the experiment, the steam was turned on the hose and allowed to blow into the air until apparently dry steam showed at the end of the hose. This end was then put into the barrel and the temperature of the water allowed to rise from 10 to 20 degrees, the water being constantly agitated. The hose was then taken out and the temperature of the water in the barrel noted. The weight was then taken and the pressure of steam during the experiment noted. From this data the quality of the steam was calculated.

In making the calculations, allowance was made for the water equivalent of the barrel used. The barrel being partly filled with water to the level used in the experiments and its temperature noted, a quantity of warm water of known temperature was added and the resulting temperature noted. Knowing the weights of water used, the equivalent of the barrel was found as follows: Multiply the added weight of water by the number of heat units lost by the warm water and divide by the heat units gained by the cold water. This quotient less the weight of cold water in the barrel is the water equivalent of the barrel.

Allowing the water to remain in the barrel for three minutes made no appreciable change in the temperature, showing that there was but little loss from radiation during each experiment, which did not generally last over two minutes.

The following formula was used in making the calculations from data derived while using this apparatus, and an examination of the results will show that they vary surprisingly.

w = weight of cold water plus water equivalent of barrel.

g = heat units corresponding to temperature of cold water, counting from 32°F.

g_1 = heat units corresponding to temperature of the mixture, counting from 32°F.

H = heat units (latent) corresponding to the temperature and pressure of steam.

g_2 = heat units (sensible) corresponding to the temperature and pressure of the steam, counting from 32°F.

w_1 = weight of water and steam added.

φ = water contained in w_1 .

$$\varphi = 1 + \frac{1}{H} \left\{ (g_2 - g_1) - \frac{w}{w_1} (g_1 - g) \right\}$$

The numerical quantities used in making these calculations were taken from Röntgen's "Thermodynamics" (DuBois' translation), and are substantially the same as other tables derived from the same source, and were used because they were familiar to the young men making the calculations.

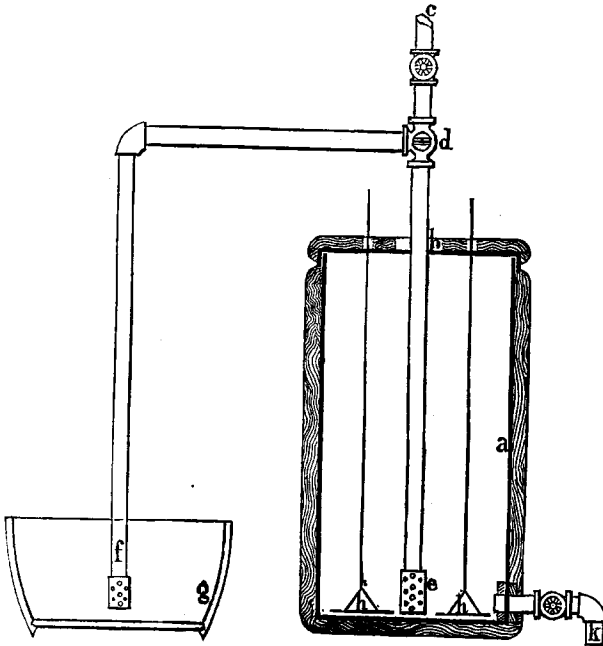


FIG. 3.

The second apparatus used was on the same general principle, and only differed from the first in matters of detail. It is shown in Fig. 3. *a* represents a tin tank, high in proportion to its diameter, and heavily covered with felt and canvas. A tin cover, *b*, fitting over this tank, had an opening in its centre for admitting steam or cold water. *c* is the pipe from the boiler, branching at the three-way cock *d*. One branch goes down into the tank *a*, and has the rose *e* at its lower end. The other branch terminates in the rose *f*, in the tank *g*, which is kept partly filled with water. *k* is the drain-pipe and valve for emptying *a*. The method of operating the calorimeter is as follows: The weight of the tank *a* is taken. It is then partly filled with water, and the weight and temperature is noted. Steam being off the pipe *c*, the three-way cock *d* is turned so that *c* and *f* are in communication. Steam is now turned on *c* and passes into the water in *g*. As soon as the pipe is heated and clear of any condensed water, the three-way cock *d* is turned and the steam allowed to pass into *a*. As soon as a sufficient quantity, say 10 pounds, has passed into *a*, the three-way cock is turned into its original position and steam is shut off *c*. *h, h* is an annular perforated plate, having two handles extending through the cover *b*, and is used to thoroughly mix the water in *a*. The temperature is now taken and also the weight of the tank and its contents. The pressure of the steam is noted, and the experiment is ended. The water equivalent of the tank is determined as for the simple barrel, and the calculations are made in the same way as before.

When this and the previous method were used at the same time, the results entirely disagreed.

The third method used was one devised by Mr. Barrus, a member of the Committee on Steam Engines, and was used on both boiler and engine tests.

Fig. 4 is a sketch of the apparatus. It consisted of a wooden vessel, *o*, mounted on a frame at the proper height for use. Inside this vessel were two partitions, so that any water passing from the centre of the vessel, must pass over one and under the second. In the centre of the vessel was a vertical cylinder, *m*, which confined the coldest condensing water to the centre of the apparatus. The condensing water passed down the pipe *A*, through a valve by which the quantity was regulated, and into the cylinder *m*, out at the bottom of *m*, and out through *c*. The pipe *j* was connected directly to the boiler or steam-pipe from which the steam was to be taken. Below the globe

facturers to take part in the exhibit. From the time of opening until the close of the exhibition the boiler-house constructed of wood, with a corrugated iron roof, and occupying the entire length of Foster street, from Thirty-second to Thirty-third streets, was a place of great interest and was visited by a large number of people. Arrangements were made and successfully carried out, whereby visitors could examine any boiler in operation without being incommoded, as is often the case in similar exhibitions, by the annoyance of ashes, dust and leaky joints. The entire building devoted to the generation of steam was well arranged and ventilated, and with good lighting facilities. The total amount of 1,800 horse-power was furnished by four Babcock & Wilcox boilers, three Harrison, one Burnham, Parry, Williams & Co. (steel), two Abendroth & Root, one Dickson & Co., Scranton, Pa., and four locomotive boilers, two of these latter being furnished each by the Pennsylvania Railroad and Reading Company. With the exception of two of the Babcock & Wilcox, these boilers were loaned for use without charge, the exhibition furnishing fuel and expense of firing. The steam pumps supplying these boilers were loaned for use by Davidson Steam Pump Company, New York, and others.

Exhibitors were furnished with power, either from shafting driven by engines under the control of the committee, or steam was supplied directly to engines installed as part of individual or company exhibits. Among the former were those of the Southwark Foundry and Machine Co., Buckeye Co., Salem, Ohio; Kensington Engine Works, Philadelphia; Straight-Line Engine Co., Syracuse, N. Y., and New York Safety Steam Power Co. Some of these firms with others, mentioned in full in the catalogue and reports, supplied individual exhibits with power direct. With the collection of boilers and engines were many new and valuable appliances for the generation and economical use of steam. For a complete list reference can be had to the report of the Committee on Tests of Boilers and Engines. Without desiring to do injustice to other members of this special committee it is but proper to mention the intelligent and faithful work done by Mr. H. W.