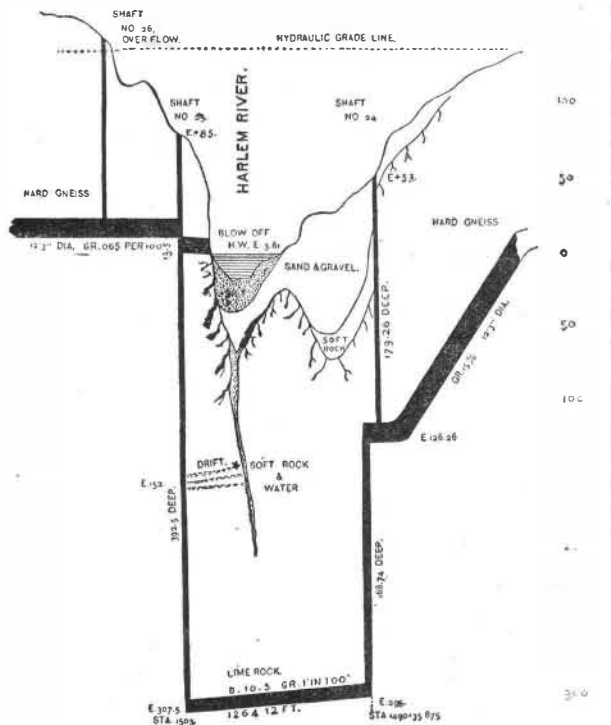


One Hundred and Thirty-fifth Street, with a rising slope of 0.065 per 100 feet, in order to drain that portion of the tunnel south of the Harlem into the Harlem River by an adit emptying into the river at shaft 25, situated on the south bank of the Harlem. Shafts 24 and 25 were constructed for the purpose of draining the tunnel under flow pressure north and south of the Harlem River, shaft 25 also serving as a pumping station to free the siphon under the river. The tunnel ends at the gate house located at One Hundred and Thirty-fifth Street, and the water is then conducted to the reservoir in Central Park by twelve lines of iron pipe, three feet in diameter. Four waste weir gate houses are located on the line, one at Pocantico River, near Tarrytown, nine and one-half miles south of Croton Lake; the second, at Saw Mill River, six and one-fourth miles further south, near Ardsley; the third at Tibbets Brook, five and one-half miles further; and the fourth at the Harlem River, seven miles below. Three gate houses serve to control and regulate the water supply through the aqueduct; the largest at Croton dam, the entrance; the second at the south end of the tunnel, One Hundred and Thirty-fifth Street, where the pipe line begins; and the third at the final terminus, in Central Park. The character of the rock varied considerably; hard, granitic, and syenitic gneiss rock was encountered, also lime rock, a soft laminated, micaceous gneiss and mica schist appeared in stretches. Disintegrated talcose rock occurred at shaft 18 south, and crushed in the strongest timbering. At shaft 30 south, some 300 feet of the tunnel were lined with iron in the form of rings bolted together, surrounded with brick and backed with rubble masonry. This was found necessary in such bad ground. Nearly every variety of tunnel experience was met with in this work.

The entire tunnel is lined with brick from end to end, forming a wall sixteen to twenty-four inches thick, and filled in from brick lining to rock face with rubble masonry. In order to obtain room for this lining the tunnel had to be excavated to a clear diameter equal to eighteen feet along the section, with an internal diameter of fourteen feet, and to fifteen feet in that part twelve feet three inches in diameter.

By far the greatest feature of the system designed for an additional water supply is the erection of Quaker Bridge dam and reservoir. Its utility and necessity are conceded, though its construction has not been finished. Its successful and permanent construction will undoubtedly become an established fact, in view of the real design and intention for which the new aqueduct has been constructed. The total height at center will be 265 feet;



the width or thickness at base will be 216 feet; width at top, 20 feet; its length at top, 1,500 feet; elevation of base, — 52 feet; elevation of flow line, + 200 feet; elevation of flood line, + 206 feet; elevation of top of rail, + 213 feet. This dam has been designed as a straight dam, and has met with difference of opinion in regard to this feature from numerous engineers.

In connection with Quaker Bridge reservoir, the erection of a dam and reservoir at Muscot Mountain, six miles above Croton Dam, is contemplated as a necessary auxiliary to Quaker Bridge reservoir. The dam would cover this territory with its back water, and would serve a sanitary purpose. In case the reservoir were drawn down at any time, the surrounding country would not be laid bare to the sun's rays, the consequences of which would be the serious contamination of the water. In order to acquire an increased storage of water above the present supply, pending the final determination and erection of the Quaker Bridge reservoir, a selection of a site on the west branch of the Croton River, near Sodom, was resolved upon. The reservoir is nearing its completion. One of the features of the Sodom dams and reservoirs is a double dam, two distinct drainage areas having two dams connected by a tunnel, so that the water can pass freely from one to the other.

The capacity of the Sodom or east branch reservoirs is about 10,000,000,000 gallons. The erection of this dam about doubles the existing storage in reservoirs and lakes located in the Croton water shed.

The Sodom or west branch reservoirs are impounded by small dams, one of them being of masonry 500 feet long, and the other an earth dam with masonry core. The Department of Public Works is erecting a reservoir on the Amawalk River, a small tributary, near the site selected for the Muscot dam, with a capacity of 7,000,000,000 gallons. This, together with existing reservoirs and lakes, and the west branch reservoirs now building, will give a total storage of 26,000,000,000.

It can be readily seen that all the water in the Croton water shed will, in a few years, be stored up for use. This has led to the investigation of the means

and measured daily consumption of water in New York.

Estimate by Mean Curve of Consumption, Daily.		Measured Consumption.*	
Year.	Million Gallons.	Year.	Million Gallons.
1842.....	12.0	1842.....	12.0
1860.....	49.0		
1861.....	51.5		
1862.....	54.0		
1863.....	56.5	1863.....	54.4
1864.....	59.2		
1865.....	62.0		
1866.....	64.8	1866.....	66.0
1867.....	67.5	1867.....	72.0
1868.....	70.5	1868.....	78.0
1869.....	73.5	1869.....	75.0
1870.....	77.0	1870.....	70.0
1871.....	80.0	1871.....	79.0
1872.....	83.5	1872.....	81.0
1873.....	87.3	1873.....	88.0
1874.....	91.0	1874.....	92.0
1875.....	95.0	1875.....	95.0

\* Commissioner's Report, August 12, 1879.

#### ESTIMATE OF FUTURE CONSUMPTION OF WATER IN NEW YORK CITY BY PROLONGING THE MEAN CURVE OF PAST CONSUMPTION.

Year.	Million Gallons.	Increase Million Gallons.	Year.	Million Gallons.	Increase Million Gallons.
1876.....	98.0	...	1889.....	168.0	7.0
1877.....	102.0	4.0	1890.....	176.0	8.0
1878.....	106.0	4.0	1891.....	184.0	8.0
1879.....	110.5	4.5	1892.....	193.0	9.0
1880.....	115.0	4.5	1893.....	202.0	9.0
1881.....	120.0	5.0	1894.....	212.0	10.0
1882.....	125.0	5.0	1895.....	222.0	10.0
1883.....	130.5	5.5	1896.....	234.0	12.0
1884.....	136.0	5.5	1897.....	246.0	12.0
1885.....	142.0	6.0	1898.....	258.0	12.0
1886.....	148.0	6.0	1899.....	272.5	14.5
1887.....	154.0	6.0	1900.....	290.0	17.5
1888.....	161.0	7.0			

The evidence of this record is that the Croton must be supplemented from some other source within a few years. The total capacity of the two aqueducts—the old and the new one—together being 350,000,000 gallons of water per day, their supply will answer all purposes for some time to come.

New York City, November 18, 1889.

#### SIBLEY COLLEGE LECTURES.—1889-90.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

#### II.—CIRCULATION OF WATER IN STEAM BOILERS.

By GEO. H. BABCOCK, of New York City.

YOU have all noticed a kettle of water boiling over the fire, the fluid rising somewhat tumultuously around the edges of the vessel and tumbling toward the center, where it descends. Similar currents are in action while the water is simply being heated, but they are not perceptible unless there are floating particles in the liquid. These currents are caused by the joint action of the added temperature and two or more qualities which the water possesses.

1. Water, in common with most other substances, expands when heated; a statement, however, strictly true only when referred to a temperature above 39° Fah. or 4° C., but as in the making of steam we rarely have to do with temperatures so low as that, we may for our present purposes ignore the exception.

2. Water is practically a non-conductor of heat, though not entirely so. If ice-cold water was kept boiling at the surface, the heat would not penetrate sufficiently to begin melting ice at a depth of three inches in less than about two hours. As therefore the heated water cannot impart its heat to its neighboring particles, it remains expanded and rises by its levity, while colder portions come to be heated in turn, thus setting up currents in the fluid.

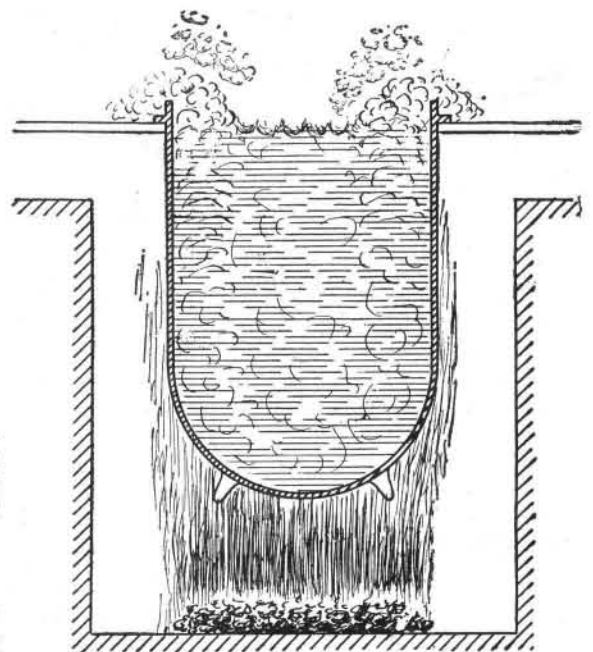
Now, when all the water has been heated to the boiling point corresponding to the pressure to which it is subjected, each added unit of heat converts a portion, about seven grains in weight, into vapor, greatly increasing its volume, and the mingled steam and water rises more rapidly still, producing ebullition such as we have noticed at first, a tumultuous lifting of the water around the edges, flowing toward the center and thence downward; if, however, the fire be quickened, the upward currents interfere with the downward, and the kettle boils over. (Fig. 1.)

It is not recorded by whom and when this action of water when heated was first noticed, though it is fair to refer it to remote antiquity. But notwithstanding it has long been well known, not until a comparatively recent date does any one seem to have considered that these currents were a necessary part of the action of water within a steam boiler, possibly because, being closed, one could not easily see what the action was therein. And even now there are more boilers made with no provision for these currents than with. The first notice we find of the recognition of its necessity is in a description of Griffiths' water tube boiler of 1821, in Mr. Alexander Gordon's "Treatise on Elemental Locomotion," about 1832, in which he says that "the principal difficulty Mr. Griffiths had to contend with was the liability to which the boiler was exposed of having all the water blown out of the tubes by force of the steam generated in the lower part, and to the want of a due circulation or ability of the water to return."

Shortly after, in 1825, we find this difficulty provided for by large return pipes, in the patent of Joseph Eve, and in 1826 in the U-tube boiler which Gurney put

upon his road locomotives. In 1831 Jacob Perkins patented means of separating the currents in small tubes, and also in large boilers, and providing for a rapid circulation of the water therein. Since that time various inventors and engineers have recognized its importance and provided more or less intelligently for it, but even at the present day great ignorance prevails as

Fig. 1.

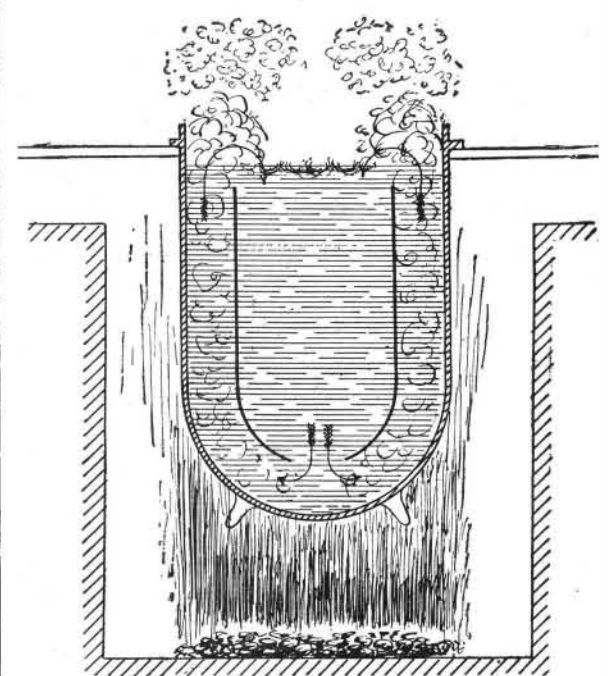


to the importance of circulation and the proper means for securing it in practice.

Let us go back to our kettle of water. We found that when we forced the fire too fiercely, it boiled over. If now we put in the kettle a vessel somewhat smaller (Fig. 2), with a hole in the bottom, and supported at a proper distance from the side, so as to separate the upward from the downward currents, we can force the fires to a very much greater extent without causing the kettle to boil over, and when we place a deflecting plate so as to guide the rising column toward the center, it will be almost impossible to produce that effect. This is the invention referred to as patented by Perkins in 1831, and forms the basis of very many of the arrangements for producing free circulation of the water in boilers which have been made since that time. It consists in dividing the currents so that they will not interfere each with the other.

But what is the object of facilitating the circulation of water in boilers? Why may we not safely leave this to the unassisted action of nature, as we do in culinary operations? We may if we do not care for the three most important aims in steam boiler construction, namely, efficiency, durability, and safety, each of which is more or less dependent upon a proper circulation of the water. As for efficiency, we have seen one proof in our kettle. When we provided means to preserve the circulation, we found that we could carry a hotter fire and boil away the water much more rapidly than before. It is the same in a steam boiler. The rapid current of water carries away the bubbles of steam as fast as they are formed upon the surface and supplies their place by other particles of water, which in their turn carry off the heat by vaporization or otherwise. Thus the efficiency of the surface is greatly increased. And

Fig. 2.



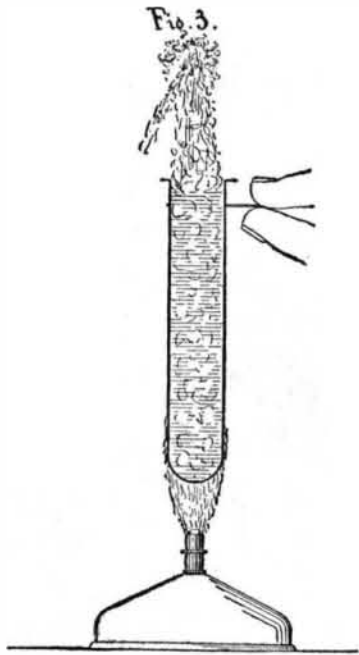
we also noticed that when there was nothing but the unassisted circulation, the rising steam carried away so much water in the form of foam that the kettle boiled over, but when the currents were separated, and an unimpeded circuit was established, this ceased, and a much larger amount of steam was delivered in a comparatively dry state. Thus circulation increases the efficiency in two ways: It adds to the ability to take up the heat, and decreases the liability to waste that heat by what is technically known as priming. There is yet another way in which, incidentally, circu-

lation increases efficiency of surface, and that is by preventing in a greater or less degree the formation of deposits thereon. Most waters contain some impurity, which, when the water is evaporated, remains to incrust the surface of the vessel. This incrustation becomes very serious sometimes, so much so as to almost entirely prevent the transmission of heat from the metal to the water. It is said that an incrustation of only  $\frac{1}{8}$  inch will cause a loss of 25 per cent. in efficiency, and that is probably within the truth in many cases. The average conductivity of underground strata, with which boiler incrustations may fairly be compared, as given by Forbes and Sir William Thomson, is but one-thirtieth of that of iron, so that an eighth of an inch incrustation added to the surface of the boiler will have the same effect as adding a second plate of iron four inches thick. Circulation of water will not prevent incrustation altogether, but it lessens the amount in all waters, and almost entirely so in some, thus adding greatly to the efficiency of the surface.

A second advantage to be obtained through circulation is *durability* of the boiler. This it secures mainly by keeping all parts at a nearly uniform temperature. Until a comparatively recent date, boilers have been built to fulfill the conditions of Rankine's class 1 of highest efficiency. "The convection taking place in the best manner by introducing the water in the coolest part of the boiler and making it travel gradually to the hottest." This class of boiler originated, I think, with the locomotive "Novelty," built by Braithwait & Ericsson, in 1829, for the famous competitive test on the Liverpool and Manchester Railroad, in October, that year, and is known as the "drop-flue" boiler. In it circulation is avoided as far as possible, keeping the bottom as cool as may be and delivering the hottest gases into the flues near the surface of the water. Though, theoretically, this arrangement has some advantages in the abstraction of heat, it renders the boiler exceedingly subject to leaks and repairs, owing to the unequal expansion of the different parts. I have known cases where for years it was necessary to have a gang of boiler makers at work every Sunday, to keep a pair of these drop-flue boilers in working condition. This style of boiler has now almost wholly disappeared, but still many boiler makers build, and engineers recommend, boilers but a little way removed therefrom, wherein absence of adequate circulation of the water causes some portions to remain cold, while others are hot. The way to secure the greatest freedom from unequal strains in a boiler is to provide for such a circulation of the water as will insure the same temperature in all parts.

3. *Safety* follows in the wake of durability, because a boiler which is not subject to unequal strains of expansion and contraction is not only less liable to ordinary repairs, but also to rupture and disastrous explosion. By far the most prolific cause of explosions is this same strain from unequal expansions.

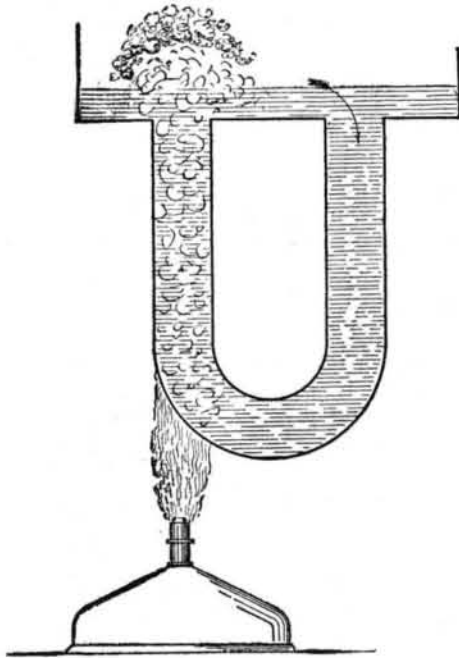
Having thus briefly looked at the advantages of circulation of water in steam boilers, let us see what are the best means of securing it under the most efficient conditions. We have seen in our kettle that one essential point was that the currents should be kept from interfering with each other. If we could look into an ordinary return tubular boiler when steaming, we should see a curious commotion of currents rushing hither and thither, and shifting continually as one or the other contending force gained a momentary mastery. The principal upward currents would be found at the two ends, one over the fire and the other over the first foot or so of the tubes. Between these the downward currents struggle against the rising currents of steam and water. At a sudden demand for steam, or on the lifting of the safety valve, the pressure being slightly reduced, the water jumps up in jets at every portion of the surface, being lifted by the sudden generation of steam throughout the body of water. You have seen the effect of this sudden generation of steam in the well-known experiment with a Florence flask, to which a cold application is made while boiling water under pressure is within. You have also witnessed the geyser-like action when water is boiled in a test tube held vertically over a lamp. (Fig. 3.)



If now we take a U tube depending from a vessel of water (Fig. 4) and apply the lamp to one leg, a circulation is at once set up within it, and no such spasmodic action can be produced. This U tube is the representative of the true method of circulation within a water tube boiler properly constructed. We can, for the purpose of securing more heating surface, extend the heated leg into a long incline (Fig. 5), when we have the well-known inclined tube generator. Now, by adding other tubes, we may further increase the heating surface (Fig. 6), while it will still be the U tube in effect and action. In such a construction the circulation is a function of the difference in density of the two columns.

Its velocity is measured by the well-known Torricellian formula,  $V = \sqrt{2gh}$ , or approximately  $V = 8\sqrt{h}$ ,  $h$  being measured in terms of the lighter fluid. This velocity will increase until the rising column becomes all steam, but the *quantity* or weight circulated will attain a maximum when the density of the mingled steam and water in the rising column becomes one-half that of the solid water in the descending column, which is nearly coincident with the condition of half steam and half

Fig. 4.

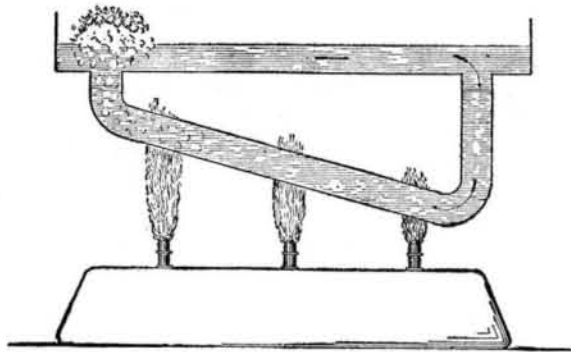


water, the weight of the steam being very slight compared to that of the water.

It becomes easy by this rule to determine the circulation in any given boiler built on this principle, provided the construction is such as to permit a free flow of the water. Of course every bend detracts a little, and something is lost in getting up the velocity, but when the boiler is well arranged and proportioned, these retardations are slight.

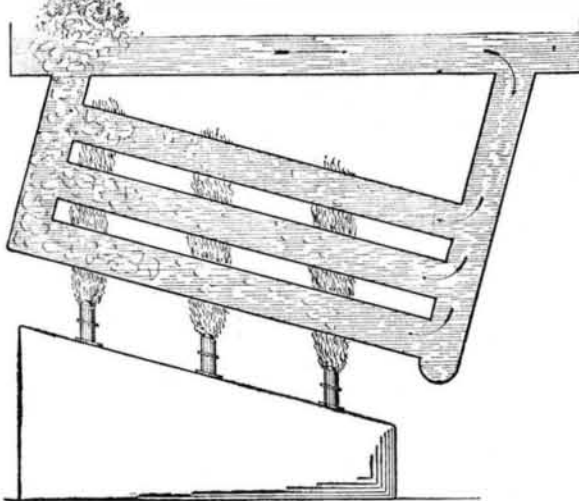
Let us take for example one of the 240 horse power Babcock & Wilcox boilers here in the university. The

Fig. 5.



height of the columns may be taken as four and one-half feet, measuring from the surface of the water to about the center of the bundle of tubes over the fire, and the head would be equal to this height at the maximum of circulation. We should therefore have a velocity of  $8\sqrt{4\frac{1}{2}} = 17.97$ , say 18 feet per second. There are in this boiler fourteen sections, each having a 4" tube opening into the drum, the area of which (inside) is 11 square inches, the 14 aggregating 154 square inches, or 1.07 square feet. This multiplied by the velocity, 17.97 feet, gives 19.18 cubic feet mingled steam and water discharged per second, one-half of which,

Fig. 6.



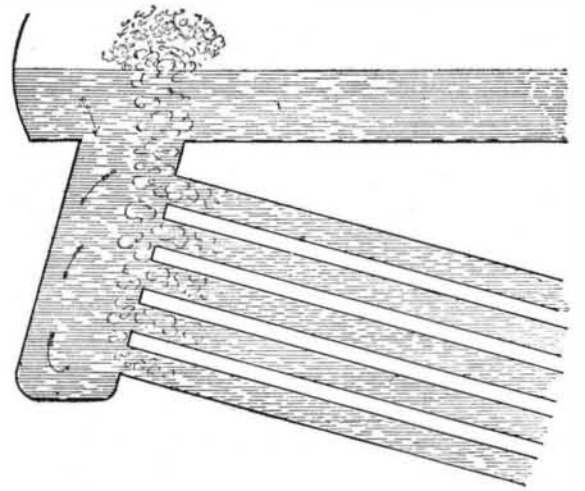
or 9.59 cubic feet, is steam. Assuming this steam to be at 100 pounds gauge pressure, it will weigh 0.258 pound per cubic foot. Hence 2.47 pounds of steam will be discharged per second, and 89.07 pounds per hour. Dividing this by 30, the number of pounds representing a boiler horse power, we get 296.9 horse power, about 23 per cent. in excess of the rated power of the boiler. The water at the temperature of steam at 100 pounds pressure weighs 56 pounds per cubic foot, and the steam 0.258 pound, so that the steam forms but 1-218 part of the mixture by weight, and

consequently each particle of water will make 218 circuits before being evaporated when working at this capacity, and circulating the maximum weight of water through the tubes.

It is evident that at the highest possible velocity of exit from the generating tubes, nothing but steam will be delivered, and there will be no circulation of water except to supply the place of that evaporated. Let us see at what rate of steaming this would occur with the boiler under consideration. We shall have a column of steam say four feet high on one side and an equal column of water on the other. Assuming, as before, the steam at 100 pounds and the water at same temperature, we will have a head of 866 feet of steam and an issuing velocity of 235.5 feet per second. This multiplied by 1.07 square feet of opening, and 3,600 seconds in an hour, gives 218,600 pounds of steam, which, though only one-eighth the weight of mingled steam and water delivered at the maximum, gives us 7,286 horse power, or over 30 times the rated power of the boiler. Of course this is far beyond any possibility of attainment, so that it may be set down as certain that this boiler cannot be forced to a point where there will not be an efficient circulation of the water. By the same method of calculation it may be shown that when forced to double its rated power, a point not expected to be reached in practice, about two-thirds the volume of mixture of steam and water delivered into the drum will be steam, and that the water will make 110 circuits while being evaporated. Also that when worked at only about one-quarter its rated capacity, one-fifth of the volume will be steam, and the water will make the rounds 870 times before it becomes steam. You will thus see that in the proportions adopted in this boiler there is provision for perfect circulation under all the possible conditions of practice.

In designing boilers of this style it is necessary to guard against having the uptake at the upper end of the tubes too large, for if sufficiently large to allow downward currents therein, the whole effect of the rising column in increasing the circulation in the tubes is nullified (Fig. 7). This will readily be

Fig. 7.



seen if we consider the uptake very large—when the only head producing circulation in the tubes will be that due to the inclination of each tube taken by itself. This objection is only overcome when the uptake is so small as to be entirely filled with the ascending current of mingled steam and water. It is also necessary that this uptake should be practically direct, and it should not be composed of frequent enlargements and contractions. Take for instance the boiler known in Europe as the De Nayer boiler, copied and sold here under another name. It is made up of inclined tubes secured by pairs into boxes at the ends, which boxes are made to communicate with each other by return bends opposite the ends of the tubes. These boxes and return bends form an irregular uptake, whereby the steam is expected to rise to a reservoir above. You will notice (Fig. 8) that the upward current of steam and water in the return bend meets and directly antagonizes the upward current in the adjoining tube. Only one result can follow. If their velocities are equal the momentum of both will be neutralized and all circulation stopped, or if one be stronger, it will cause a back flow in the other by the amount of difference in force, with practically the same result.

In the original Root boiler, many of which were sold, but of which none are now made, and very few are still in use, the inventor claimed that the return bends and small openings against the tubes were for the purpose of "restricting the circulation," and no doubt they performed well that office; but excepting for the smallness of the openings, they were not as efficient for that purpose as the arrangement shown in Fig. 8.

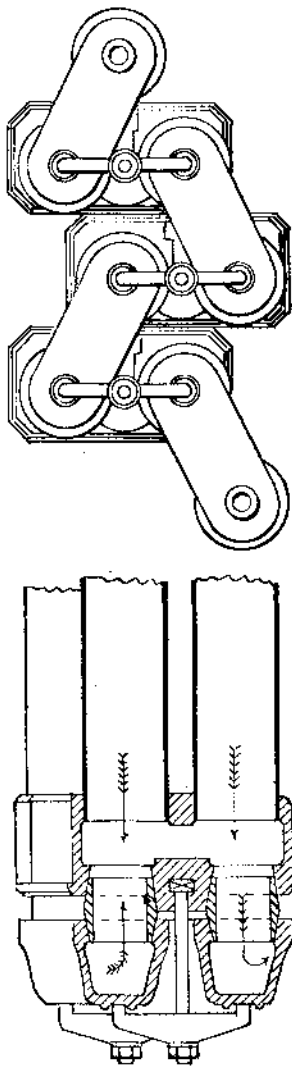
Another form of boiler, first invented by Clarke or Crawford, and lately revived, has the uptake made of boxes into which a number, generally from two to four tubes, are expanded, the boxes being connected together by nipples (Fig. 9). It is a well-known fact that where a fluid flows through a conduit which enlarges and then contracts, the velocity is lost to a greater or less extent at the enlargements, and has to be gotten up again at the contractions each time, with a corresponding loss of head. Many years ago some one proposed to carry water across the Hackensack River to Jersey City by means of a pipe, which was to be so jointed as to permit of being laid like a cable from a boat and adapt itself to the bed of the river. The joints were to be elbows fitted and bolted so as to permit of motion around the transverse axis; and with an idea to avoid the loss due to the many changes of direction, these elbows were enlarged somewhat like tobacco pipes, with the bowls laid together. To test the matter, a model was made to scale, carefully smoothed on the inside to reduce friction, but when tried it proved that, even with these elbows so carefully shaped to render the enlargement and contractions as gradual as possible, there would have been no head left long before the pipe reached the opposite shore, and the plan was abandoned. The same thing occurs in the construction shown in Fig. 9. The enlargements and contrac-



tions quite destroy the head and practically overcome the tendency of the water to circulate.

A horizontal tube stopped at one end, as shown in Fig. 10, can have no proper circulation within it. If moderately driven, the water may struggle in against

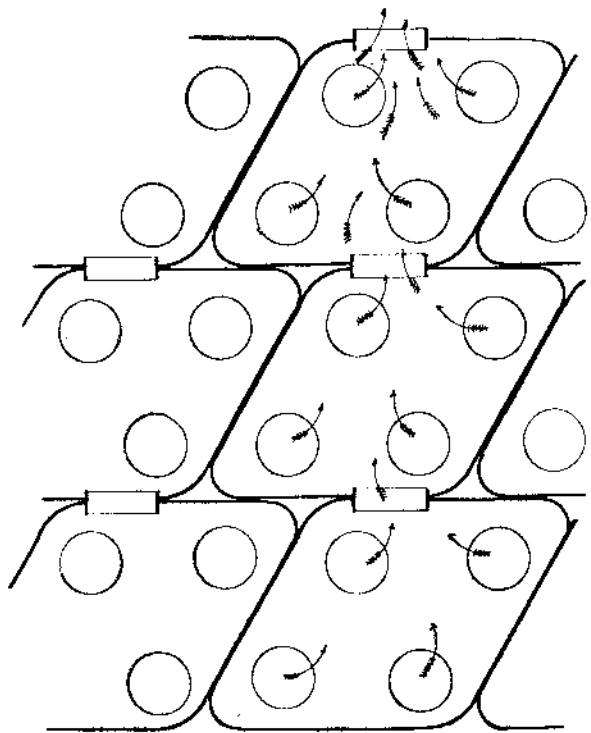
Fig. 8.



the issuing steam sufficiently to keep the surfaces covered, but a slight degree of forcing will cause it to act like the test tube in Fig. 3, and the more there are of them in a given boiler, the more spasmodic will be its working.

I have thus enlarged upon the proper circulation of water in water tube boilers because they seem destined to be the boiler of the future, and because of having seen thirty or forty kinds of water tube and sectional boilers appear and disappear in the last twenty-five years, by far the larger portion of which have failed

Fig. 9.

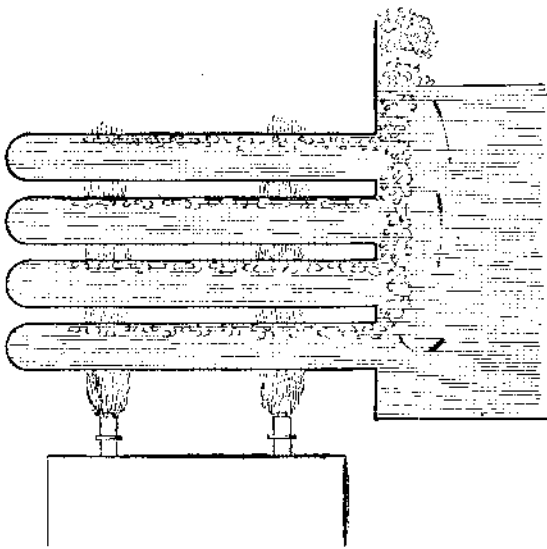


through want of adequate provision for such circulation.

The experiment with our kettle (Fig. 2) gives the clew to the best means of promoting circulation in ordinary shell boilers. Steenstrup or "Martin" and "Galloway" water tubes placed in such boilers also assist in directing the circulation therein, but it is almost impossible to produce in shell boilers, by any means, the circulation of all the water in one continuous

round, such as marks the well constructed water tube boiler.

The point of entrance of feed water in any boiler has also something to do with the circulation, and much to do with durability. Care should always be taken to introduce it at some point where, if not immediately heated to the temperature of the water in the boiler, it shall not come in contact with any portion of the metal until it is so heated. If introduced into the bottom or the mud drum, it will keep below the hotter water and set up serious strains in the structure. I recollect the late Mr. Dickerson showing with great satisfaction as an evidence of superior economy, on board the Algonquin, that when there was 80 lb. of steam on the boiler he could wash his hands in water drawn from the blow-off cock. Rankine mentions with approbation the same condition in the Earl of Dundonald's boiler, but it is a condition to be avoided always. The feed water should be introduced into the current of hot water, where it will the soonest possible mingle



with and become of the same temperature as the rest of the water.

As I have before remarked, provision for a proper circulation of water has been almost universally ignored in designing steam boilers, sometimes to the great damage of the owner, but oftener to the jeopardy of the lives of those who are employed to run them. The noted case of the Montana and her sister ship, where some \$300,000 were thrown away in trying an experiment which a proper consideration of this subject would have avoided, is a case in point; but who shall count the cost of life and treasure not, perhaps, directly traceable to, but, nevertheless, due entirely to such neglect in design and construction of the thousands of boilers in which this necessary element has been ignored? If these few facts and hints may induce you who are to be the engineers of the near future to give due consideration to this important subject when designing the boilers of the future, my aim will have been fulfilled. Thanking you for your kind attention to a subject which, though treating of a flowing liquid, is itself necessarily somewhat dry, I will, in order that a circulation may again be established among you, bid you good night.

#### A THREE-CYLINDER GAS MOTOR.

MR. LALBIN, engineer of arts and manufactures, has just constructed a new gas motor which has been recently tested at Nantes upon a boat containing twenty persons. The speed obtained was seven miles per hour.

One of the principal advantages of this motor is its lightness as compared with other gas engines. Thus, a half-horse power motor, which can be applied to a tricycle, weighs but 88 lb.; a one horse power weighs 133 lb.; and the five horse power, which was tested on a boat, as above mentioned, weighs but 440 lb.

This latter, in a vertical plane, occupies a circumference of 100 inches, the eduction pipe included, and the fly wheel, which weighs 110 lb., is but 34 inches in dia-

sort of box containing wicking. This latter, in the boat referred to, was placed under the deck, and the oil reservoir under one of the seats.

The air sucked in by the motion of the pistons passes through the wicking saturated with petroleum, in the carburetor, and becomes charged with combustible vapors in sufficient quantity, regulated at will by a valve maneuvered by hand. A Leclanche battery produces the spark necessary for igniting the gas.

The consumption of petroleum is eleven ounces per horse and per hour, say a little less than a pint per hour, so with a 12½ gallon reservoir, the five horse power engine is capable of furnishing an effective run of 20 hours.

Figs. 1 and 2 give sections of the motor; Fig. 3 gives a transverse section of a cylinder, showing the valve box, H; Fig. 4 gives a front view of a cylinder, with a partial section of the valve box; Figs. 5 and 6 show the arrangement of the gearing for effecting the motion of the cam cylinder, that regulates the distribution; Figs. 7, 8 and 9 represent the arrangement for reversing the motor.

Each cylinder contains a piston, P, connected directly by a connecting rod, Q, with the one crank in common, M, and is provided with a throttle valve, H, and an eduction valve, K.

Ignition is effected at F through an extra current spark, produced by a Leclanche battery. These three cylinders have a common action and control one another, that is to say, the explosion in each cylinder produces, aside from the disposable work, the work necessary for the maneuvering of the cylinder of the piston which is to furnish the subsequent explosion, so as to make it suck the detonating mixture and compress it until the moment at which it is to explode.

The cylinder that carries the cams that control the various services of each cylinder revolves in a direction opposite that of the crank shaft, and at half the velocity, and V in the direction of the crank, and V' in that of the distribution. The consequence of such a distribution is that the explosion takes place from one pair of cylinders to another, and with the greatest regularity. As the thrust upon the crank is almost constant, the diameter of the fly wheel may be greatly diminished. The diameter of the pistons of the 5 h. p. engine is five inches, and their stroke is 5¼ inches. The space occupied in a lengthwise direction does not exceed 32 inches, and the motor weighs 440 lb. The engine is reversed through the arrangement shown in Figs. 7, 8 and 9, by means of a lever that causes the cam cylinder to slide in such a way that either the system of cams of Fig. 8 or of Fig. 9 is, according to the direction of running, presented to it under the tappets.

The detonating gas is furnished by the vapors of petroleum mixed with the proper quantity of air, the mixture being varied in such a way as to give the maximum of power, say 400 revolutions, or the minimum, which is 100 revolutions per minute.—*Le Genie Civil*.

#### SMOKELESS EXPLOSIVES.\*

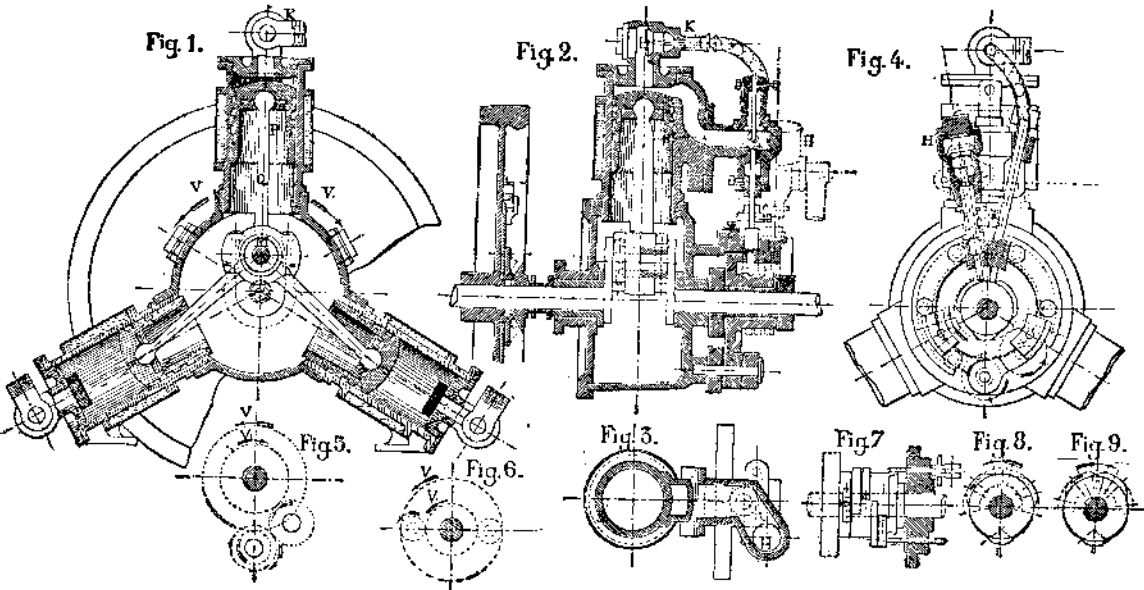
By Sir FREDERICK ABEL, F.R.S.

THE production of smoke which attends the ignition or explosion of gunpowder is often a source of considerable inconvenience in connection with its application to naval or military purposes, its employment in mines, and its use by the sportsman, although occasions not unfrequently arise during naval and military operations when the shroud of smoke produced by musketry or artillery fire has proved of important advantage to one or other, or to both, of the belligerents during different periods of an engagement.

Until within the last few years, however, but little, if any, thought appears to have been given to the possibility of dispensing with or greatly diminishing the production of smoke in the application of fire arms, excepting in connection with sport. The inconvenience and disappointment often resulting from the obscuring effects of a neighboring gun discharge, or of the first shot from a double-barrel arm, led the sportsman to look hopefully to guncotton, directly after its first production in 1846, as a probable source of greater comfort and brighter prospects in the pursuit of his pastime and in his strivings for success.

A comparison between the chemical changes attending the burning, explosion, or metamorphosis of guncotton and of gunpowder serves to explain the cause of the production of smoke in the latter case and the reason of smokelessness in the case of guncotton.

While the products of explosion of the latter consist



LALBIN'S THREE-CYLINDER GAS MOTOR.

meter. The gases escape into the water, and the cooling of the cylinders is secured through a small automatic pump.

The petroleum is contained in an iron vessel of 12½ gallons capacity, provided with a screw coupling by means of which it is connected with the carburetor, a

exclusively of gases, and of water which assumes the transparent form of highly heated vapor at the moment of its production, the explosive substances classed as gunpowder, and which consist of mixtures

\* Friday Evening Discourse delivered by Sir Frederick Abel, F.R.S., at the Royal Institution of Great Britain, on January 31, 1890.