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Report of the Experiments with the Turbine Water Wheels at Philadelphia.

We have received the official report of the Chief Engineer, Henry P. M. Birkinbine, Esq., giving a full account of the experiments with turbine water wheels made at the Fairmount Water Works, Philadelphia, during the winter of 1859-'60. We have already given the general results of these experiments, but from the very important character of the information obtained, and the extensive interest which is felt in it, we are induced to give a more detailed description of them, accompanied by an illustration of the apparatus employed in trying the capacity of the the wheels. We are satisfied that these experiments were as distinguished for their impartial fairness as they were for their open publicity, and the rational and satisfactory nature of the method adopted. The following is Mr. Birkinbine's description of the apparatus.

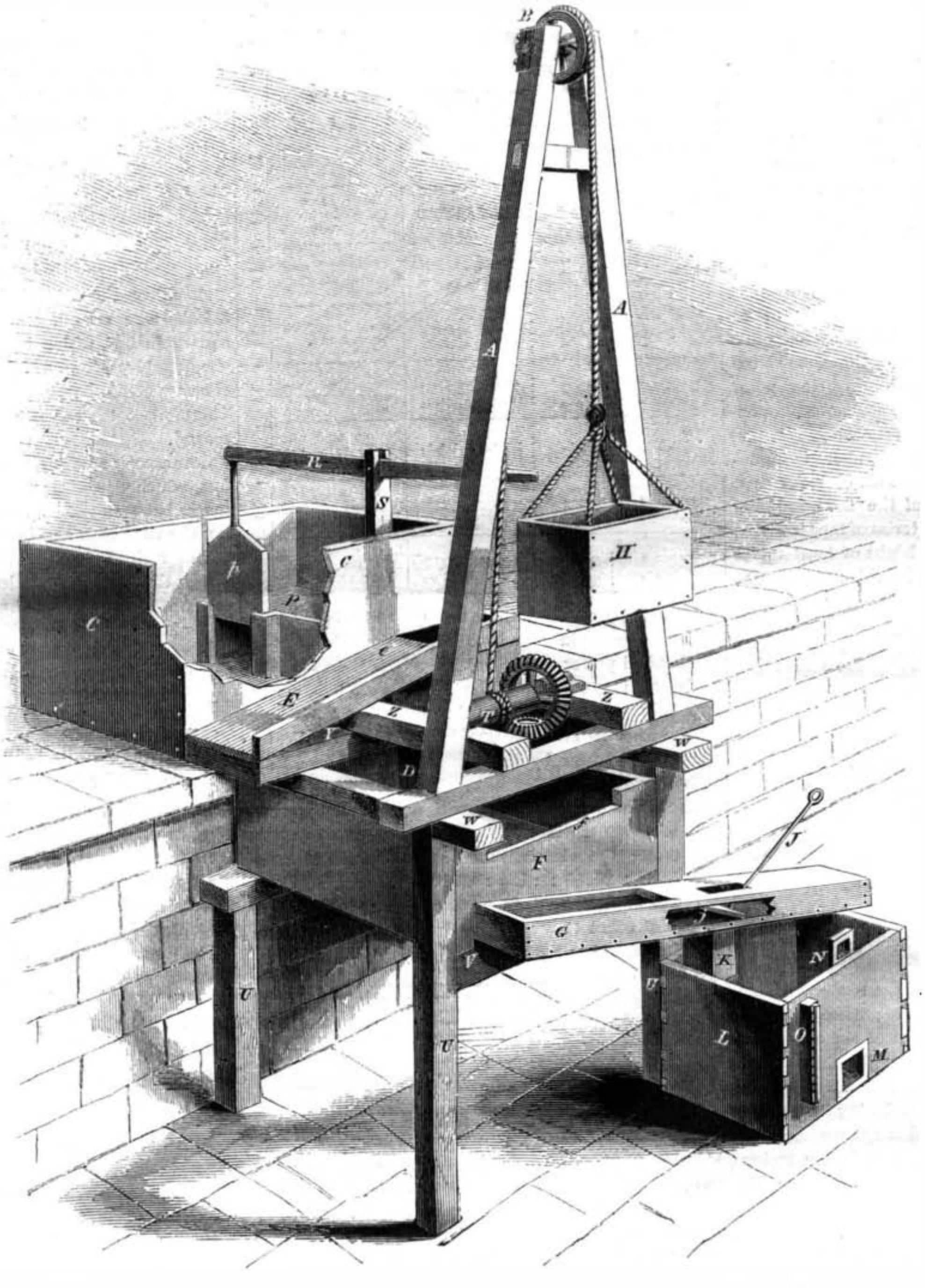
The large box, C, forms a reservoir for supplying the models with water ; it communicates with the penstock, D, by way of the trunk, P, and a waste notch adapted to it, for preventing overflow of the box. The valve, *p*, operated by the lever, R, having its fulcrum in the post, S, opens and closes the communication with the trunk and reservoir at the pleasure of the operator.

The models to be tested were placed in the box, F, which served as a wheel-pit, with their inlet water ways connected directly to the side of the penstock, D. Those wheels which had no gates of their own were provided with one at the opening of the penstock into the inlet of the wheel. After the water had performed its work in the wheels, it flowed into the box, F, and escaped through the notch, *f*, into the trough, G, by which it was either conveyed from the apparatus into the river, or conducted into the measuring box, L, through the spout, K.

When the discharge valve, *j*, was open, any water passing down the trough fell into the measuring box ; but when the valve was shut, the water passed over its back, and was delivered outside. This valve was operated by the rod, J, extending through a slit in the top of the trough, the side of which is removed to show the arrangement.

The measuring box, L, is emptied through the opening, M, by drawing the slide, N, and has a graduated glass tube, O, fitted to its side, for exhibiting the exact depth of the water within.

To the top of the penstock, D, was fitted an overflow spout, E, for carrying off any excess of head of water from the models, it being important to maintain an unvarying head over them. The perpendicular distance between the summit, *e*, of the overflow, E, and the notch, *f*, was six feet.



The shaft of each model was connected by suitable gearing to the shaft of the drum, T. Upon this drum was wound a rope, which, passing over the sheave, B, revolving in bearings at the tops of the posts, A A, lifted the weight box, H.

The posts, A A, were held in position by guys which extended back, and were fastened on the upper level of the wall.

The whole apparatus was supported on and connected with the framing, U U V W X Y and Z.

The box, C, received a constant supply of water, through pipes connected with one of the pump mains.

The measuring box was five feet every way, inside.

The apparatus is isometrically represented to a scale of one-eighth of an inch to the foot.

The hight of the wall against which the apparatus stood is fifteen feet.

Operation.—After the model to be tested was properly connected with the penstock, D, and drum shaft, T, the reservoir, C, was filled with water, and kept constantly supplied to the point of overflow.

The weight box, H, was then charged and carefully weighed, and the valve, J, thrown upon its seat to pass the water outside the measuring box. This valve was operated by an assistant, whose business it was to open and close it promptly when the signals were given.

An assistant was stationed at the lever, R, to control the valve, *p*, and keep the water in the penstock, during the experiment, just at the point of overflow.

The rope was well stretched before it was used, and during the course of the experiments two pieces of tape were fastened around it at a convenient distance apart for observation (usually 25 feet), which distance was measured when the whole weight of the loaded box was suspended. Before trial, the box was raised and lowered several times by running the wheel, to ascertain that all the machinery was properly adjusted, and to give the rope every opportunity of becoming fully stretched for the trials. The distance between the tapes was again measured, and also frequently during the trial, to enable the operator to eliminate every possibility of error from the stretching or contracting of the rope.

When the wheel was fully underway, and at the moment the first tape was passing a fixed point, a signal was given to open the discharge valve, and direct the tail water into the measuring box ; when the second tape was passing the same point, another signal was given to close the valve, and conduct the tail water away from the apparatus ; after which the wheel was stopped, and the weight box allowed to run back to the place of starting.

If the depth of overflow from the top of the penstock varied in any experiment, or in different experiments, the operator at the inlet valve noted the amount of variation from observations made at the summit of the spout, and allowed for it accordingly.

An adjustable slide was fitted to the notch, *f*, to enable the operator to maintain a uniform overflow of the tail water from the wheels. Upon the surface of the water in the wheel box, F, rested a float, from which projected a rod vertically, to the top of the penstock; this rod exhibited to the operator above the level of the water in the wheel box, and served as a check to any neglect of duty on the part of the operator at the adjustable notch, *f*. For wheels which vented water more rapidly than others, the adjustable notch and float indicator were necessary to ascertain the actual difference of level of the head and tail water during every trial, which difference is the true head or fall acting on any water wheel.

It will be noticed that the amount of water which escaped from the wheel during the experiment, into the measuring box, was only that which was used to raise a known weight a measured hight, after the wheel had attained a uniform speed.

It is reasonable to assume that the amount of water required to start different wheels may vary very considerably; and it is possible that a wheel which gives a higher ratio of useful effect while in motion, may require more water to get it underway than one which gives a lower ratio. It is also certain that, at the commencement of the trials, the rope would be drawn to different tensions; perhaps, in some instances, it would hang loosely from the sheave, in which case the wheel would vent a great deal of water before the weight would be lifted at all. It was to avoid errors from these sources that the apparatus was constructed in the manner described; to ascertain the useful effect of each wheel only while in motion and during the performance of its work, omitting altogether the uncertain conditions of starting and stopping.

The different parts of the apparatus were so disposed that the observer at the penstock overflow could see the level of the water in the wheel box, as indicated by the float rod; and the observer stationed to signal the passage of the tape over the measuring point could, by his ear, note the time of closing and opening the discharge valve, and make allowance, if necessary, for any fore or after movement which might unavoidably occur while closing it. This observer was, at the same time, within sight of the float rod and penstock overflow, and, in the interim of tape transits, could detect, at a glance, the hight of head under which the wheel was working. In this manner, one observer could watch the performances of the others, and act as a check to any neglect of duty on their part; and any person interested in the correct testing of the wheels could see the ropes, water levels and discharge valve from one station point, and thus observe for himself the faithfulness of the operators and the progress of the trials. The time required for each wheel to perform its work was taken by an observer, who stationed himself on an upper platform at a point favorable for observing the exact moment of transit of the tapes.

During the whole course of the experiments the same persons gave the same signals and operated the same parts of the apparatus, and no pains were spared in securing the greatest degree of exactness in every manipulation of the machine.

The amount of weight to which the box was loaded was varied in different experiments; these weights, together with all the essential data of the trials, appear in the tables which are given under the head of each wheel. A correct platform scale for weighing the box was kept at the apparatus during the whole time of the experiments, and any person who wished to be satisfied of its correctness before trying his wheel, could have it tested upon making that wish known.

REMARKS ON THE TABLE.

Under the heading, "Ratio of Useful Effect," are the quotients, which are found by dividing the product of the weight in box and hight raised, by the product of the weight of water discharged and hight of head and fall.

The following example will show the process by which the ratio of useful effect is obtained.

The area of the bottom of the box was constantly 24.86 square feet.

A cubic foot of water was taken at 62.5 lbs. avoirdupois.

Then 1,000×25=25,000.

And 24.86×3.266×62.5×6=30447.285.

And 25000÷30447.285=.8210=ratio of useful effect sought for.

SUMMARY OF EXPERIMENTS.

NOTE.—In the trials marked *, the diameters and circumferences given are *means*, measured at the centers of discharge orifices.

		4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Ratio of useful effect.	Cubic feet of water discharged per second.	Area of orifices between guides.	Area of orifices in wheel.	Velocity of water through guides.	Head and fall.	Ratio of velocity of water through guides to theoretic velocity.	Velocity of water through wheel in feet per second.	Ratio of velocity of water through wheel to theoretic velocity.	Revolution of wheel per minute.	Velocity of circumference of wheel in feet per second.	Ratio of circumferential to theoretic velocity.	Diameter of wheel.	Load upon wheel at the circumference.
				sq. in.	sq. in.	ft. pr sc.	feet.							inches.	lbs.
Jonval and vertical discharge.	*Geyelin, 2d	.8210	3.122	44.6	37.70	10.08	6.	.5129	11.92	.5929	191.4	13.9	.7074	16.62	69.29
	*Collins, 2d	.7662	2.837	35.4	31.35	11.54	6	.5871	13.03	.6679	144.2	11.06	.5629	17.55	73.79
	*Stevenson, 1st	.7335	3.353	41.25	30.90	11.70	6.02	.5941	15.62	.7931	169.7	13.52	.6717	18.25	70.21
	*Geyelin, 1st	.6799	3.911	42.6	42.	13.22	6.04	.6703	13.41	.6799	222.9	12.66	.6423	13.	70.06
	*Collins, 1st	.4734	3.372	40.	39.5	12.14	6.10	.6126	12.29	.6263	129.3	9.75	.4920	17.25	55.73
	*Stevenson, 2d	.8777	2.976	42.	32.	10.2	6	.5204	13.39	.6831	162.	12.47	.6331	18.75	79.09
	*Andrews & Kalbach, 3d	.8197	3.065	51.5	31.	8.57	6.	.4361	14.23	.7241	297.	15.34	.7806	11.75	61.3
	*Andrews	.6205	3.116	45.	26.	12.55	6.	.6387	21.73	1.1020	276.9	14.22	.7236	11.75	53.73
	*Andrews & Kalbach, 2d	.7591	3.295	45.	31.	......	6	......	......	......	......	......	......	11.75	......
Centrif'l or outward discharge.	*Smith's Parker's, 4th	.7569	4.963	49.	35.	14.58	6.	.7420	20.52	1.0350	235.9	18.74	.9533	18.25	75.80
	* " 3d	.7467	4.820	49.	35.	14.19	6.	.7216	19.85	.9460	216.7	17.29	.8790	18.25	78.20
	* " 2d	.6726	3.298	40.	35.	11.87	6.10	.6055	13.56	.6897	396.8	14.74	.7498	8.50	57.94
	Littlepage	.5415	4.375	63.	50.	10.00	6.05	.5066	12.60	.6380	......	......	......	24.00	......
Centripetal or inward discharge.	Blake	.7169	3.039	37.4	52.6	11.70	6.	.5953	8.320	.4233	179.1	14.08	.7106	18.	58.16
	Tyler	.7123	3.431	34.5	103.0	14.32	6.	.7121	4.797	.2440	149.	11.72	.5965	18.	69.09
	Merchant's Goodwin	.6412	3.673	39.3	123.0	13.09	6.	.6661	4.182	.2128	79.17	10.38	.6649	30.	82.91
	Rich	.6132	2.430	50.	33.0	7.00	6.10	.3531	10.65	.5384	244.8	16.59	.8370	15.5	34.30
	Mason's Smith	.6324	2.928	36.25	......	11.63	6.05	.5894	......	......	187.6	14.72	.7410	18.	47.33
	Monroe	.5359	2.711	22.68	57.7	17.21	6.	.8756	6.775	.3441	131.6	10.22	.5085	17.75	42.28

It will be noticed that the quantity 30447.285, which expresses in pounds the whole possible effect or mechanical power of the water used in the above experiment, is greater than the quantity 25,000, which expresses in the same terms the amount of work done by the wheel. The difference between them indicates the loss of power by the use of the wheel and attached machinery.

The following proportion will express the percentage of power utilized by the model wheel, when acting under the circumstances given in the table:—30447.285 : 25000 : : 100 : 82.10.

If the models were arranged according to the ratio of useful effect they gave, beginning with the highest, the following list would indicate the order:—

Stevenson's second wheel	.8777
Geyelin's second wheel	.8210
Andrews & Kalbach's third wheel	.8197
Collins' second wheel	.7662
Andrews & Kalbach's second wheel	.7591
Smith's Parker's, fourth trial	.7569
Smith's Parker's, third trial	.7467
Stevenson's first wheel	.7335
Blake	.7169
Tyler	.7123
Geyelin's (double) first wheel	.6799
Smith's Parker's second wheel	.6726
Merchant's Goodwin	.6412
Mason's Smith	.6324
Andrews' first wheel	.6205
Rich	.6132
Littlepage	.5415
Monroe	.5359
Collins' first wheel	.4734

It will be noticed, by reference to the tables, that the *highest* ratio obtained is given in the above list, and not the average of each series. The figures present, therefore, the best work done by each wheel.

Taking into account the fact that each and every wheel was tried under an unvarying head, and that whatever error there might be in the precise relations which should obtain between the diameter of the wheel, the number and area of its issues and weight to be raised, to make the experiment a perfect one; it was perhaps compensated for by the opportunities offered to alter the model, change the ratio of gearing and the weights to be raised. For these reasons, the results of these experiments may be considered the fairest show of the merit which the models possessed.

The wheels are classified according to the direction of discharge from the issues of their buckets.

The first class includes those in which the discharge was vertical. Geyelin's second, Collins' first and second, and Stevenson's first and second, were all Jonval wheels, and all discharged downward, while Andrews' and Andrews & Kalbach's discharged upward.

The second class includes the outward discharge wheels. The head water passed into these wheels between their hubs and the inner ends of the buckets, and thence outward centrifugally from the periphery of the wheels.

The third class includes the inward discharge wheels. They were all surrounded by scrolls, and the head water entered all of them and was discharged from the issues toward their axes, except Mason's, which discharged downward. The power of the head water was directed by the scroll around the wheel, but its motion through the wheel was centripetal.

The figures in the fourth column were found by the process explained above.

The figures of the fifth column were found by dividing the number of cubic feet of water discharged by the number of seconds which elapsed during the discharge. For example:—

24.86×3.266÷26=3.122, the amount of discharge sought for.

The figures in the sixth and seventh columns were obtained from actual measurements of the models,

The "velocity of water through guides" in feet, per second, will be found in the eighth column, and is obtained as follows:—

As above, the cubic feet of discharge per second is 3.122. The area of orifices through guides is 44.6 square inches, which is 44.6÷144=.3097 foot; and the quantity discharged in feet per second, divided by the area of discharge, gives the velocity of discharge. Therefore, 3.122÷.3097=10.08=velocity in feet per second.

Column nine gives the hights of head and fall in feet, which were taken by measurement of the distances between the levels of head and tail water during the time each and every trial was made.

The ratios of actual to theoretic velocity of the water through the guides are given in the tenth column, and are found thus: The theoretic velocity of water issuing from an orifice under pressure, is equal to that of a falling body at a hight equal to the head which gives said pressure.

Therefore, $\sqrt{6\times64.33}$=19.65=theoretic velocity in feet per second.

The actual velocity is 10.08, found in column eight.

Hence, 10.08÷19.65=.5129=ratio sought for.

The figures in column eleven are found in the same manner as those in column eight, by substituting the areas from column seven for those of column six; and the figures of column twelve are found by the same process as those of column ten, by substituting the velocities of column eleven for those of column eight.

The "revolutions of wheels per minute," in column thirteen, were deduced from the ratios of gearing and velocity of drums. Thus: the actual diameter of drum was $9\frac{1}{16}$ inches; the diameter of rope was $1\frac{1}{4}$ inches, but the effective circumference of the former was 2.5836 feet.

Then 25÷2.5836=9.6763=revolutions of drums in 26 seconds.

And 9.6763×60÷26=22.33=revolutions of drum per minute.

Therefore 22.33 × 60 ÷ 7=191.4=revolutions of wheel per minute.

Having the revolutions of the wheels per minute, the "velocities of the circumferences of the wheels," in feet, per second, in column fourteen, are easily found.

Column sixteen contains the diameters of the model wheels, which were obtained by actual measurements of the same.

To get the velocity of circumference in feet per second, we have the diameter in inches=16.62.

Then, 16.62×3.1416÷12=4.35=circumference of wheel in feet.

And 191.4×4.35÷60=13.876=the velocity sought for.

Column fifteen gives the "ratios of circumferential to theoretic velocity." In the process for obtaining the ratios in column ten, it was shown that the theoretic velocity of discharge of water under the given head was 19.65 feet per second.

Then $13.9 \div 19.65 = .7074$ = ratio sought.

Column seventeen gives the "loads in pounds at the circumference of wheels," which are found by the following process:—

Above, it is stated that the revolutions of wheel and drum per minute are respectively 191.4 and 22.33, and, in this experiment the load on drum was 1,000 lbs.; therefore—

191.4 : 22.33 : : 1000 : 116.66,

which latter is the load on the wheel. Now, the diameter of the wheel is 16.62 inches, and the circumference in feet corresponding to this is 14.35, as above, while the circumference of drum is 2.5836 feet.

Therefore, 4.35 : 2.5836 : : 116.66× : 69.24, which latter is the load at the circumference of the wheel in pounds.

THE CHEMICAL HISTORY OF A CANDLE.

By Professor Faraday.

A Course of Six Lectures (adapted to a Juvenile Audience) Delivered before the Royal Institution of Great Britain.

LECTURE V.—(Continued.)

Oxygen present in the Air—Nature of the Atmosphere—Its Properties—Other Products from the Candle—Carbonic Acid—Its Properties.

Here is something that you can have a pull at when I have finished to-day. It is a little apparatus of two hollow brass hemispheres, closely fitted together, and having connected with it a pipe and a cock, through which we can exhaust the air from the inside, and though the two halves are so easily taken apart while the air is left within, yet you will see when we exhaust it by and by, no power of any two of you will be able to pull them apart. Every square inch of surface that is contained in the area of that vessel sustains fifteen pounds by weight, or nearly so, when the air is taken out; and you may try your strength presently in seeing whether you can overcome that pressure of the atmosphere.

Here is another very pretty thing—the boy's sucker, only refined by the philosopher. We young ones have a perfect right to take toys, and make them into philosophy, inasmuch as now-a-days we are turning philosophy into toys. Here is a sucker, only it is made of india-rubber; if I clap it upon the table, you see at once it holds. Why does it hold? I can slip it about, but if I try to pull it up, it seems as if it would pull the table with it. I can easily make it slip about from place to place; but only when I bring it to the edge of the table can I get it off. It is only kept down by the pressure of the atmosphere above. Here is a couple of them; if you take these two and press them together, you will see how strong they stick. And, indeed, we may use them as they are proposed to be used, to stick against windows or against walls, where they will adhere for an evening, and serve to hang anything on that you want. I think, however, that you boys ought to have experiments that you can make at home; and so here is a very pretty experiment in illustration of the pressure of the atmosphere. Here is a tumbler of water; suppose I were to propose to you to turn that tumbler upside down, so that the water should not fall out, and yet not keep it in by my hand, but merely by using the pressure of the atmosphere; could you do that? Take a wine glass, either quite full or half full of water, and put a flat card on the top; turn it upside down, and then see what becomes of the card and of the water. The air cannot get in because the water, by its capillary attraction round the edge, keeps it out.

I think this will give you a strong notion of what you may call the materiality of the air, when I tell you that that box contains a pound of it, and this room more than a tun, and you will begin to think that air is something very serious. I will make another experiment to convince you of this positive resistance. There is that beautiful experiment of the pop gun, made so well and so easily, you know, out of a quill, or a tube, or anything of that kind; where we take a slice of potato, for instance, or an apple, and take the tube and cut out a pellet, as I have now done, and push it to one end. I have made that end tight; and now I take another piece and put it in; it will confine the air that is within the tube perfectly and completely for our purpose; and now I shall find it absolutely impossible, by any force of mine, to drive that little pellet close up to the other. It cannot be done; I may press the air to a certain amount, but if I go on pressing, long before it comes to the second, the confined air will drive the front one out with a force something like that of gunpowder; for gunpowder is in part dependent upon the same action that you saw in this case.

Here is an experiment which I saw the other day, and was much pleased with, as I thought it would answer our purpose here. (I ought to have held my tongue for four or five minutes before I began this experiment, because I depend upon the strength of my lungs for the success of it.) By the proper application of air, I expect to drive this egg out of one cup into the other by the force of my breath, but if I fail it is in a good cause, and I do not promise success, because I have been talking more than I ought to do, to make the experiment succeed.

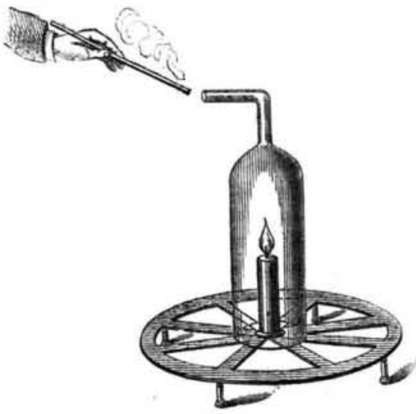
[The lecturer here tried the experiment, and succeeded in blowing the egg from one egg cup to the other.]

You see that the air which I blow goes downward between the egg and the cup, and makes a blast under the egg, and is thus able to lift a heavy thing—for a full egg is a very heavy thing for air to lift. If you want to make the experiment, you had better boil the egg quite hard first, and then you may very safely try to blow it from one cup to the others with a little care.

I think I have now kept you long enough upon this property of the weight of the air, but there is another thing I should like to mention. You saw the way in which, in this pop gun, I was able to drive the second piece of potato half or two-thirds of an inch before the first piece started, by virtue of the elasticity of the air; just as I pressed into the copper bottle the particles of air by means of the pump. Now, this depends upon a wonderful property in the air, namely, its elasticity, and I should like to give you a good illustration of this. It is this: if I take anything that confines the air properly, as this membrane, it is able to contract and expand so as to give us a measure of the elasticity of the air, and to confine in it a certain portion of air; and then, if we take the atmosphere off from the outside of it, just as in these cases we put the pressure on—if we take the pressure off, you will see how it will then go on expanding and expanding, larger and larger, until it will fill the whole of this bell jar, showing you that wonderful property of the air, its elasticity, its compressibility, and expansibility, to an exceedingly large extent; and this is very essential for the purposes and services it performs in the economy of creation.

We will now turn to another most important part of our subject, remembering that we have examined the candle in its burning, and have found that it gives rise to various products. We have the products, you know, of soot, of water, and of something else which you have not yet examined. We have collected the water, but have allowed the other things to go into the air. Let us now examine some of these other products.

Here is an experiment which, I think, will help you in part in this way. We will now put our candle there, and place over it a chimney, thus. I think my candle will go on burning, because the air passage is open at the bottom and at the top. In the first place, you see the moisture coming—that you know about. It is water produced from the candle by the action of the air upon its hydrogen. But besides that, something is going out at the top; it is not moisture—it is not water—it is not condensible; and yet, after all, it has very singular properties. You will find that the air coming out of the top of our chimney is nearly sufficient to blow the light out I am holding to it, and if I put the light fairly opposed to the current, it will blow it quite out. You will say, that is as it should be, and I am supposing that you think it ought to do so, because the nitrogen does not support combustion, and ought to put the candle out, since the candle will not burn in nitrogen. But is there nothing else there than nitrogen? I must now anticipate—that is to say, I must use my own knowledge, to supply you with the means that we adopt for the purpose of ascertaining these things, and examining such gases as these. I will take an empty bottle—here is one—and if I hold it over this chimney, I shall get the combustion of the candle below sending its results into the bottle above; and we shall soon find that this bottle contains, not merely an air that is bad as regards the combustion of a taper put into it, but having other properties.



Let me take a little quick lime and pour some common water on to it—the commonest water will do. I will stir it a moment, then pour it upon a piece of filtering paper in a funnel, and we shall very quickly have a clear water proceeding to the bottle below, as I have here. I have plenty of this water in another bottle, but, nevertheless, I should like to use the lime water that was prepared before you, so that you may see what its uses are. If I take some of this beautiful clear lime water, and put that into this jar, which has collected the air from the candle, you will see a change coming about. Do you see that that water has got quite milky? Observe, that will not happen with air merely. Here is a bottle filled with air, and if I put a little lime water into it, neither the oxygen nor the nitrogen, nor anything else that is in that quantity of air will make any change in the lime water—it remains clear and perfect, and no shaking of that quantity of lime water with that quantity of air in its common state will cause any change; but if I take this bottle with the lime water and hold it so as to get the general products of the candle in contact with it, in a very short time, you see, we shall have it milky—there is the chalk, consisting of the lime which we used in making the lime water, combined with something that came up from the candle—that other product which we are in search of, and which I want to tell you about to-day. This is a substance made visible to us by its action, which is not the action of the lime water itself, but it is something new to us from the candle. And then we find this white powder produced by the lime water and the vapor from the candle, appears to us very much like whiting or chalk, and when examined it does not prove to be exactly the same substance as whiting or chalk. So we are led, or have been led, to observe upon the various circumstances of this experiment, and to trace this production of chalk to its various causes to give us the true knowledge of the nature of this combustion of the candle—to find that this substance issuing from the candle is exactly the same as that substance which would issue from a retort if I were to put some chalk into it and make it red hot with a little moisture; you would then find that exactly the same substance would issue from it as from the candle.

But we have a better means of getting this substance, and in greater quantity, so as to ascertain what its general characters are. We find this substance in very great abundance in a multitude of cases where you would least expect it. All limestones contain a great deal of this gas which issues from the candle, and which we call *carbonic acid.* All chalks, all shells, all corals, contain a great quantity of this curious air. We find it fixed in these stones, for which reason Dr. Black called it "fixed air"—finding in these fixed things like marble and chalk—he called it fixed air because it lost its quality of air, and assumed the condition of a solid body. We can easily get this air from marble. Here is a jar containing a little muriatic acid, and here is a taper which, if I put it to that jar, will show only the presence of common air. There is, you see, pure air down to the bottom; the jar is full of it. Here is a substance—marble, a very beautiful and superior marble, and if I put these pieces of marble into that jar, a great boiling apparently goes on. That, however, is not steam; it is a gas that is rising up, and if I now search the jar by a candle, I shall have exactly the same effect produced upon the taper as I had from the air which issued from the end of the chimney over the burning candle. It is exactly the same action, and caused by the very same substance that issued from the candle; and in this way we can get carbonic acid in great abundance—we have already nearly filled the jar. We also find that this gas is not merely contained in marble. Here is a vessel in which I have put some common whiting chalk, which has been washed in water, and deprived of its coarser particles, and so supplied to the plasterer as whiting. Here is a large jar containing this whiting and water, and I have here some strong sulphuric acid, which is the acid you might have to use if you were to make these experiments (only in using this acid with limestone, the body that is produed is an insoluble substance, whereas the muriatic acid produces a soluble substance that does not so much thicken the water). And you will seek out a reason why I take this kind of apparatus for the purpose of showing this experiment. I do it because you may repeat in a small way what I am about to do in a large one. You will have just the same kind of action, and I am evolving in this large jar carbonic acid exactly the same in its nature and properties as the gas which we obtained from the combustion of the candle in the atmosphere. And no matter how different the two methods by which we prepare this carbonic acid, you will see, when we get to the end of our subject, that it is all exactly the same, whether prepared in the one way or in the other.

We will now proceed to the next of our experiments with respect to this gas. What is its nature? Here is one of the vessels full, and we will try it as we have done so many other gases—by combustion. You see it is not combustible, nor does it support combustion. Neither, as we know, does it dissolve much in water, because we collect it over water very easily. Then you know that it has an effect and becomes white in contact with lime water, and when it does become white in that way, it becomes one of the constituents to make carbonate of lime or limestone.

Now, the next thing is to show you that it does dissolve a little in water, and therefore that it is unlike oxygen and hydrogen in that respect. I have here an apparatus by which we can produce this solution. In the lower part of this apparatus is marble and acid, and in the upper part cold water. The valves are so arranged that the gas can get from one to the other. I will set it in action now, and you see the gas bubbling up through the water, as it has been doing all night long, and by this time we shall find that we have this substance dissolved in the water. If I take a glass and draw off some of the water, I find that it tastes a little acid to the mouth; it is impregnated with carbonic acid; and if I now apply a little lime water to it, that will give us a test of its presence. This water will make the lime water turbid and white, which is the carbonic acid test.

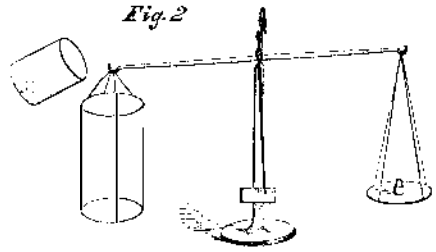
Then it is a very weighty gas; it is heavier than the atmosphere. I have put their respective weights at the lower part of this table, along with, for comparison, the weights of the other gases we have been examining:—

	PINT.	CUBIC FOOT.
Hydrogen..............	$\frac{3}{4}$ grs.	$\frac{1}{12}$ oz.
Oxygen................	$11\frac{9}{10}$	$1\frac{1}{3}$
Nitrogen..............	$10\frac{4}{10}$	$1\frac{1}{6}$
Air...................	$10\frac{7}{10}$	$1\frac{1}{5}$
Carbonic acid.........	$16\frac{1}{3}$	$1\frac{9}{10}$

A pint of it weighs $16\frac{1}{3}$ grains, and a cubic foot weighs $1\frac{9}{10}$ ounces, almost two ounces. You can see by many experiments that this is a heavy gas. Suppose I take a glass containing nothing else but air, and this vessel containing the carbonic acid; and suppose I pour a little of this gas into that glass, I wonder whether any has gone in or not; I cannot tell by the appearance, but I can in this way [introduces the taper]. Yes, there it is, you see; and if I were to examine it by lime water, I should find it in the same way. I will take this little bucket, and put it down into the well of carbonic acid—indeed we too often have real wells of carbonic acid—and now, if there is any carbonic acid I must have got to it by this time, and it will be in this bucket, which we will examine with a taper. There it is, you see; it is full of carbonic acid.

I have another experiment by which I will show you its weight. I have here a jar suspended at one end of a balance—it is now equipoised, but when I pour this carbonic acid into the jar on the one side, which now contains air, you will see it sink down at once, because of the carbonic acid that I pour into it. And now I examine this jar with the lighted taper. I will find that the carbonic acid has fallen into it, and it no longer has any power of supporting combustion. If I blow a soap bubble, which, of course, will be filled with air, and let it fall into this jar of carbonic acid, it will float. But I shall, first of all, take one of these little balloons filled with air. I am not exactly sure where the carbonic acid is; we will just try the depth, and see whereabouts is its level. There you see we have this bladder floating on the carbonic acid, and if I evolve some more of the carbonic acid, you will see the bladder lifted up higher. There it goes; the jar is nearly full, and now I will see whether I can blow a soap bubble on that and float it in the same way. [The lecturer here blew a soap bubble, and allowed it to fall into the jar of carbonic acid, when it floated in it midway.] It is floating as the balloon floated, by virtue of the greater weight of the carbonic acid than of the air. And now, having so far given you the history of the carbonic acid, as to its sources in the candle, as to its physical properties and weight, when we next meet I shall show you of what it is composed, and where it gets its elements from.

Fig. 2



ROMANCE OF THE STEAM ENGINE.

ARTICLE XVIII.

IMMENSE INCREASE OF ENGINES,

Our article this week being principally of a statistical and reflective character, is not, as usual, illustrated with an engraving. We have now brought down the chronicles of the steam engine to 1800, when the patent, extended to Watt, by the Act of Parliament, for twenty-five years, expired and was thrown open to the public. It was supposed that numerous new improvements would at once be brought into the field by other inventors, and that the firm of Bolton & Watt, which had enjoyed the monopoly so long, would be eclipsed. A new era in steam improvements was announced to commence, and, assuredly, this was really the case, but not in the sense anticipated. Owing to the exclusive manufacture of engines being in the hands of the Soho company, a public prejudice prevailed against its members, and many manufacturers, who were not aware of the great benefits conferred upon the world by the invention, hung back, as it were, from using steam engines, under the idea that when the patent expired they would obtain engines at much lower prices. It is stated that in London, in 1800, engine power to the extent of only 650 horses was all that was in operation; in Manchester, 450-horse power; in Leeds, 300; while on the whole continent of America there were only four steam engines—all Watt's. One of these was in New York, two in Philadelphia, and the other in Virginia.

When the patent was opened to the public, there was certainly a considerable rush made by millwrights—the only mechanical engineers of the time—to make and improve the engine, but the whole of them failed of success excepting those who copied Watt's engine in every essential particular. There was, however, a great and sudden demand made for new engines, and it is stated as an extraordinary fact, in proot of the long-continued monopoly of a patent not being beneficial to the patentees themselves, that in the first five years after the patent had expired, Bolton & Watt sold twice the number of engines that they had during an equal time when they possessed the sole right to manufacture them in England. The same company has transmitted the business to their descendants, who still carry on the manufacture at Soho on a most extensive scale, and they furnished the screw engines for the *Great Eastern*.

Since their first engine was built, in 1770, up to the present date, they have constructed 1,650 engines, of an united power equal to 177,000 horses; and the steam power of Great Britain, in ships, locomotives, and manufactories, is estimated at no less than 10,000,000 horses, or about one hundred millions of men.

It is not alone by the development and application of a new power to arts and commerce, for abridging human labor, that the steam engine has proven to be the modern apostle of civilization, but by the concentration of so vast a power into a very limited space. Results are now achieved that would have been deemed miraculous two hundred years ago. Some idea of this may be formed when we conceive a steamship, such as the *Vanderbilt*, driven across the ocean with a power equal to that of 2,000 horses drawing it; or a locomotive weighing only 24 tuns snorting along at the rate of 40 miles an hour, with a power equal to more than 200 horses. At the present day we cannot justly estimate what the steam engine has done for us. Had we lived before it was introduced, and had we seen the clumsy and inefficient machines which it superseded, we could have formed a more intelligent opinion of its benefits. There is one interesting case on record, however, which throws much curious light on this particular; it is that of the celebrated water engines at Marly, France.

In 1682, Louis XIV. had machinery erected at the village of Marly, upon the Seine, by the great engineer Rennequin, of Liège, to raise water for the town of Versailles. It was a gigantic specimen of the race of mechanical megalosaurians. The water was raised by fourteen large water wheels and a series of pumps, pipes, cranks and rods, remarkable for their ingenious complexity and the wonderful noise which they made while working. Dessaguliers said "the engine at Marly covers a mile in length of ground, its breadth is greater than that of the river Seine. It is a stupendous machine. It is stated to have cost over eighty million of French livres"—about $20,000,000. This machinery for raising water was held to be one of the glories of old France; no other country could show such a vast, ingenious and powerful machine. No sooner, however, was Watt's engine in successful operation than France became ashamed of what its people were formerly proud of, and Watt himself was sent for to construct an engine for Marly. It is said that one of his 50-horse engines, afterwards erected there, raised more water than the whole mile in length of the old machinery.

French Treatment of Croup.

A paper on this dangerous malady was lately communicated to the French Academy of Sciences, by Dr. Ozanan, who has devoted especial attention to this disease since 1849, and has made a great number of experiments with chemical agents in treating it. It is stated in a report of his paper that the chloride of potassium dissolves the false membrane in the throat in the course of 24 hours; chloride of sodium dissolves it in 36 hours; a solution of bromide potassium (1 part to 99 of water) dissolves it in 12 hours, and glycerine has the effect of softening it in 24 hours. Dr. Ozanan prefers alkalies as dissolvents in treating croup, but he quotes a peculiar case of successful treatment with a solution of common salt. A country physician in France, in 1860, while attempting to cauterize the throat of a patient with a stick of caustic, to his great dismay found the caustic sucked out of his fingers, and swallowed. In terror, he hastily prepared a strong solution of common salt as an antidote to counteract the effects of the poison, when to his own surprise it not only effected this object, but cured the croup also. Common salt, then, is a most simple and excellent agent for croup.

SPIRALS OF PLANTS.—It is a well known fact that certain plants grow spirally, some tending to the right and others to the left. Some new light has lately been shed upon this subject by Professor Wiedeman, who, in a communication to the Royal Society, London, attributes the phenomena to positive and negative electric currents. He states that in some experiments made by him with iron wire, he found that when he twisted it in the manner of a right-handed screw, after the passage of an electric current through it, the point at which the current entered always became a positive pole; and when he twisted it to the left hand, the point of entrance became a negative pole, and the wire magnetized. Currents of electricity flow through all plants.