HEAT AND LIGHT.

[Report of a recent lecture by Professor John Tyndall, before the Royal Institution.]

History shows us two different philosophical schools trying to account for the visible universe. The one school bases itself upon speculation, and the other on observation and experiments, the one trying, as it were, to develop a universe out of its own consciousness, the other seeking patiently after the outward facts of the universe, and through them after the principles that connect them. It is needless to say that in our day the school of experience has gained the upper hand. Indeed it is common, in philosophical books, to say that, in the investigation of Nature, you cannot go beyond experience. Take the idea of atoms, for example. No doubt this notion was first derived by the ancient philosophers from the observation of small sensible particles of matter. But in transmuting them to atoms, they so diminished the size of these particles as to place them entirely beyond the boundary of experience.

Most physical minds of the present day believe in atoms and molecules, or groups of atoms, though none of us have ever seen either atoms or molecules. In fact, you can have no explanation of the objects of experience without invoking the aid of objects lying beyond experience; we cannot possibly reach the roots of natural phenomena without the help of atoms and molecules. We figure them as the constituents of all bodies.

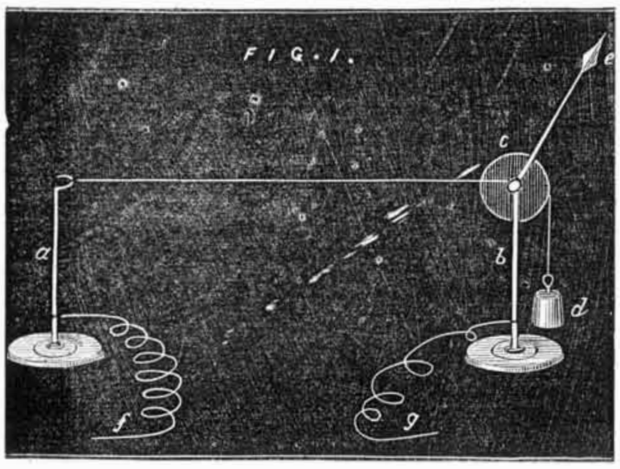


FIG. 1.

It is the play of the power we call heat among these atoms and molecules which is to occupy us during these lectures. In front of the table is stretched a platinum wire, which can be warmed by passing an electric current through it; the wire passes over a wheel, to which a straw index is attached, and a small weight is hung at the end of the wire. You are to figure that wire as an assemblage of atoms, held near each other by their mutual forces, but not in contact with each other. Heat forces them more widely apart.

The platinum wire stretched between the two stands, *a b* (Fig. 1), is lengthened when it is heated. This can be done by causing an electric current to pass through it. The wire is fastened to the hook at the top of the stand, *a*, and is carried round the axle of the small wheel, where it is made fast; over the periphery of the wheel is a cord from the weight, *d*, which keeps the wire in a state of tension; to the wheel itself is fixed the straw with a paper attached to it to act as an index, *e*. The platinum wire is pulling in one direction, and the weight is pulling in the other direction, but if the platinum wire is released the weight will instantly predominate, and the index will fall. That it does so is shown by pressing the top of the stand, *a*, towards *b*; now, making contact with the wires from a battery, at *f* and *g*, the wire becomes hot, and the index falls. Stopping the current, the wire contracts, and the index comes back again.

But here electricity might be supposed to have something to do with the effect.

Here are two wooden stands, A and B (Fig. 2), with plates of brass, P P′, riveted against them. At present the bar of iron, C, is not long enough to stretch from one support to the other. I will support them on two little projections of wood attached to the stands at P P′. One of the plates of brass, P, is connected with one pole of a voltaic battery, D, and from the other, P′, a wire proceeds to the electric alarm bell, E; and again from that instrument a wire returns direct to the pole of the battery.

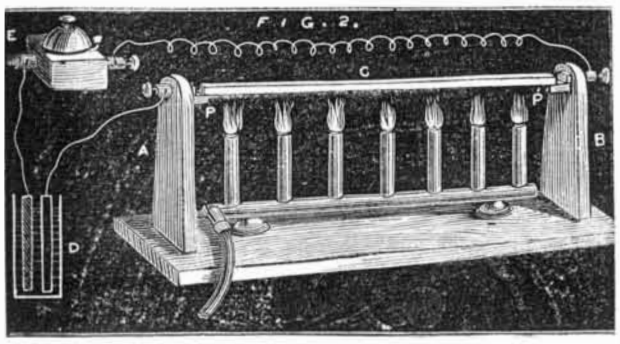


FIG. 2.

At the present moment the only break in the circuit is due to the insufficient length of the bar of iron to bridge the space from stand to stand. Underneath the bar is a row of gas jets, which I will now ignite; the bar is heated, the metal expands, and in a few moments will stretch completely across from plate to plate. When this occurs, the current passes and the signal bell rings, as you hear. Throwing a little water on the bar, after the gas is extinguished, the bar shrinks, the circuit is broken, and the bell ceases to sound.

The contraction of a bar of metal, which has been heated, is a very powerful force. The contractile force of cooling has been applied by engineers to draw leaning walls into an upright position.

The bar of iron, A (Fig. 2), is red hot; it has a hole through it at B, through which the cold bar of steel, C, is inserted; it is then dropped into the Y shaped supports, D E, and screwed up tight by the thumb screw at F; the whole arrangement stands in a trough; and water being poured over the bar, A, it contracts, and does so with such an exertion of force that the bar at B is broken into two pieces.

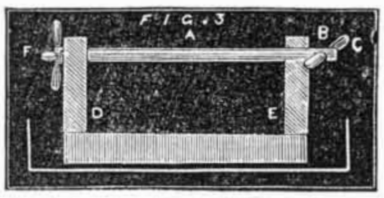


FIG. 3

But bodies expand in very different degrees, and it is necessary to devise instruments which are capable of measuring very small changes of volume. Among the most delicate of these is the apparatus before you. At the bottom of the sketch, Fig. 3, B represents the upper end of an upright bar of metal; on the top of this bar rests a little brass stem, S, the top of which acts as a fulcrum to the plate of agate, A. The arm, C, above the plate, moves on a pivot, which you see marked by a dot; a very little pushing of this arm causes it to move through a greater space than the body which pushes it. Attached to this arm is a piece of the hairspring of a watch, and that is carried round an axis, X, upon which is a mirror, M, upon which a beam of light, H, is made to impinge. Now, if you conceive the end of the bar to be lifted, and to push the arm upwards, it will cause the mirror to rotate, and the beam will travel with it, but with twice its velocity. Thus, in this experiment, instead of a straw, a ray of light is used as an index. It is exceedingly sensitive; clasping the bars of metal with both hands causes a sufficient elongation to bring the luminous index from the ceiling to the floor. Pouring a little alcohol upon it causes, by its evaporation, sufficient chilling to send the index back with great velocity; again clasping tbe bars, it is again brought downwards.

Putting tires on wheels, while they are still hot, is a familiar example of the way this contractile force is utilized.

Thus we make ourselves acquainted with the sensible fact of expansion. We are here in the domain of experience, but there is something within us which prevents us from resting there. What is the internal mechanism which produces this expansion? Here, again, we must help ourselves to conceptions by reference to the visible world. An experiment will make the matter clear.

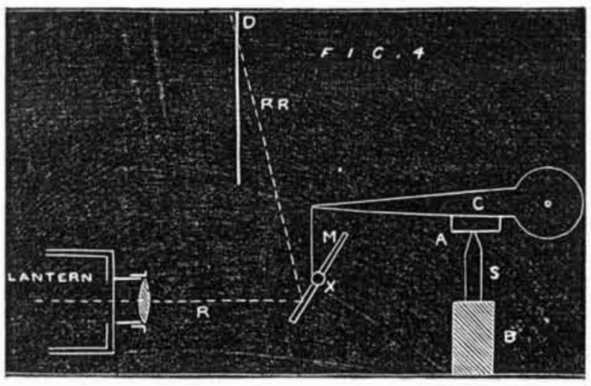


FIG. 4

On heating this flaccid bladder over a ring burner, turning it in the hand at the same time, it becomes smooth and tight.

In a very natural way, this fact of the expansion of atmospheric air was transferred from the region of experience into the region of atoms and molecules. It was assumed that the atoms were surrounded by atmospheres—atmospheres of heat or caloric; and the expansion of bodies by heat was supposed to be due to the swelling of these atmospheres. We have here that theory of heat which regarded heat as a free elastic matter, surrounding the atoms of molecules of bodies as the atmosphere surrounds the earth.

We can, as I have already said, make no attempt at explaining natural phenomena without resorting to a mental imagery of this kind. The first effort at explanation is an effort of the imagination. But having assumed a distinct and definite cause, it is a duty, which Science never neglects, to verify or confute the assumption by comparing its consequences with observed facts.

The notion of calorific atmospheres was thus tested and found wanting; and it was the founder of this Institution, whose life and doings have been recently sketched so admirably by Dr. Bence Jones, who offered the most striking experiments and the most powerful arguments against it.

Count Rumford contended that heat could not be a kind of fine matter, because its supply by friction is inexhaustible which matter is not. He contended that his experiments proved heat to be motion. And there was another great name, also associated with this Institution, who soon afterwards rendered it in the highest degree probable that the origin of light was a vibratory motion; and inasmuch as heat resembles light so closely, and in most cases preceded and accompanied it, the notion became irresistible that heat also was a kind of vibratory motion.

But how on this assumption is expansion of bodies by heat to be accounted for? Well, it requires no great effort of the imagination to see that when the atoms are oscillating to and fro, they require a greater amount of room than when they are at rest. In this one case the atom occupies a space measured by its own diameter; in the other it virtually occupies the line along which it oscillates.

Though the amplitude of a vibration be very small, its intensity may be great; striking a tuning fork, it is set in vibration, but the vibrations are so minute that they are well nigh imperceptible. If, however, two cork balls are suspended, as at *a a′*, Fig. 5, about a quarter of an inch away from each limb of the tuning fork, *c*, the greater space required by the fork when in a state of vibration is shown by the violence with which the balls are thrown to *b b′*.

Another example is furnished by the brass rod, *a b*, Fig. 6. When rubbed with a piece of flannel, having some powdered resin sprinkled on it, it is thrown into longitudinal vibration. The center, *s*, is a node, and remains still; but the two free halves elongate and contract in rapid alternation. I apply the rubber more briskly, and the balls *a* and *b* are thrown off with violence every time they come in contact with the ends of the rod.

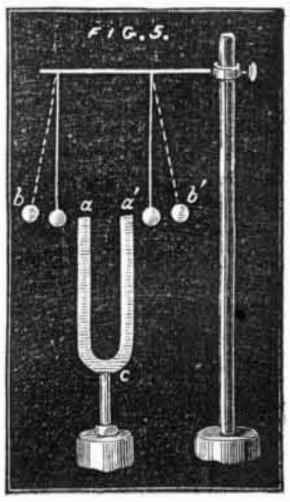


FIG. 5.

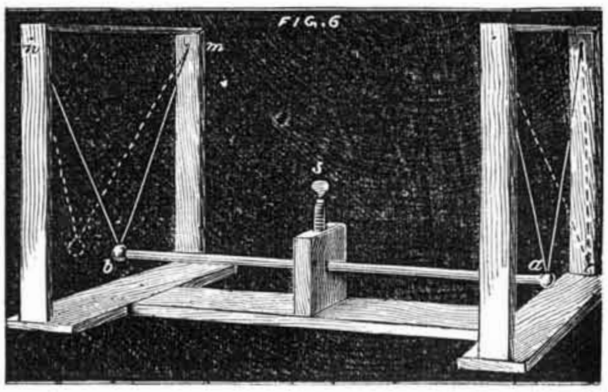


FIG. 6

In this case the amplitude of the vibration is so small that no eye can detect it, and still it is capable of projecting the ivory balls violently into space.

But the energy of those small vibrations to which we give the name of heat is immensely greater.

Dip the hand into a finger glass until the water in it is warmed one degree. An amount of energy is withdrawn from that hand sufficient to project that water to a hight of 772 feet, or if the degree be centigrade, to a hight of 1390 feet above the earth's surface—three times the hight of St. Paul's.

Let us follow this vibratory motion to its consequences. As the temperature of a solid body increases, its atoms oscillate more and more widely, the body in consequence expanding more and more. A point, or temperature, is at length attained when the hold which the atoms of the most refractory bodies exert upon each other is so loosened that the atoms are enabled to glide round each other with freedom. When this occurs, the liquid state sets in. You must not imagine cohesion destroyed in liquids, for very strong cohesive power may be associated with the power of free liquid sliding of the atoms over each other.

In the body of a liquid, each atom or molecule is surrounded on all sides by its neighbors, and thus prevented from flying away; but it requires no great stretch of imagination to see that at the surface, where on one side they are entirely uncontrolled, the molecules may be jerked away from the liquid altogether. This, in fact, is the conception of the vaporous or gaseous state of matter now prevalent. The temperature of gases—that, in fact, which keeps them in a state of gas—is supposed to be a motion of translation instead of a motion of vibration. The gaseous molecules fly through space; striking against the surfaces by which they are surrounded, striking against each other—and recoiling like little elastic balls. Here, for instance, is a vessel covered with india rubber, which is now quite flat. The air, according to this new conception, is hitting the opposite sides of the india rubber with equal force. It is, therefore, in *equilibrio*, and will remain so till the forces on the two sides become unequal.

Placed on the plate of an air pump, directly exhaustion of the air within the vessel commences, there is a loss of projectile energy on the part of the air in the interior, and the air on the exterior, retaining all its original power, drives the india rubber before it, forming a hollow within the bell glass of the air pump.

The pressure of the atmosphere being known, and the weight of the gases that compose it being known, it is easy to calculate the velocity with which the atoms must strike against a surface in order to produce the pressure. Of course the lighter the atoms, the greater must be their velocity.

The velocities of the following gaseous atoms at 32° Fah. are:

Oxygen	1·514 feet a second.
Nitrogen	1·616 " "
Hydrogen	6050 " "

If the gases be heated, their velocity is augmented and the pressure correspondingly increased.

Extreme care is necessary in determining the coefficients of expansion. Such constants are the foundation stones of science; and no higher sincerity was ever exercised by man than in determining them.

Examples of solid coefficients:

Copper	from	1·000,000	expands to	1·000,017
Lead	"	1·000,000	"	1·000,029
Iron	"	1·000,000	"	1·000,012
Zinc	"	1·000,000	"	1·000,029
Glass	"	1·000,000	"	1·000,0080
Platinum	"	1·000,000	"	1·000,0088

The last is almost the same as that of glass: hence the possibility of fusing platinum into wires with glass tubes for eudiometric and other purposes. Were the coefficients different, the fracture of the glass would be inevitable during the contraction in cooling.—*Mechanics' Magazine.*

THE STEAMSHIP "EGYPT."

Our full page engraving represents the steamship *Egypt*, a splendid vessel lately built at Liverpool for the Atlantic National line of steamers.

She is 450 feet 6 inches in length, which is more than two thirds as long as the *Great Eastern;* her breadth of beam is 44 feet, and depth of hold 36 feet. She registers 5,150 tuns gross. Her engines are on the compound principle, and are of 3,000 horse power. They are supplied with steam by six double boilers arranged in two sets of three each, which carry a pressure of 75 pounds to the square inch.

She is a complete four decker. Her spar deck is flush fore and aft, the cabin entrances and skylights being the only obstructions on it. This and the deck below are plated with steel and planked with pine. The two lower decks are plated with iron amidships, where the general strain of the machinery is felt, and are also planked with pine. She carries four masts and two funnels. Her ability to spread canvas equals that of any vessel afloat, while her rate of steaming is fourteen knots an hour. The lower masts are of iron, and the lower yards and lower topsail yards are made of steel. She has steering apparatus amidships as well as aft, and is provided with five steam winches, which work the pumps, hoist the sails, and load and discharge the cargo. The saloons, staterooms, and officers' rooms are heated by steam pipes. Between the spar and main decks are accommodations for all the first class passengers, officers, and crew, besides cooking galleys, ice houses, etc.; and the entire space between the main and next lower deck is left free for the steerage passengers.

The workmanship throughout the vessel is of the highest class, and her construction is such that more than ordinary comforts are afforded to the steerage passengers.

Sensible Suggestions about Patents.

Mr. Wm. T. Hamilton, writing to the *Engineer*, gives expression to some very practical ideas on the Patent law question now before Parliament. His suggestions apply with equal force to the American Patent law, which is based on that of England. He says:

The simple system which I would propose would be that every inventor should have patent protection, as, of course, for certain proper periods, for every invention or alleged invention, no matter whence he may have taken the primary idea. I would give him protection, not only for his own original ideas, but for utilizing the abandoned ideas of others. Why not? It would hurt no one. This patent right should of course be defensible upon its being shown by any one else that he had had the same idea in practical operation prior to the date of the patent. Here commercial user would find its proper place. It would of course save to the public every useful invention now in operation; it would injure no one, while it would open a wide field for inventors.

Thus, then, the only patent question which would arise would be one of priority of practice. This would always be a simple one, even for the county court. The issue would be not whether perhaps abstract ideas were original, but whether palpable processes were identical, and which of them had been first used. Commercial usage is notorious and of easy proof. I would thus take commercial usage not as the basis of protection, but as the element by which to prove priority; such a system would have the great charm of being almost self acting. The mere existence of such a public counterpoise would keep inventors in the right path for their own sakes. What they now fear is not what is in the light, but what is in the dark. By all means let there be competent authorities to settle these questions of priority in the last resort. The judge of the county court might be stupid; or some cases might involve very nice distinctions as to the application or principles or as to identity, or as to what is or is not essential in a scientific point of view. Let there also be libraries and museums and open registries, carefully classified, with every other possible source of information, free to inventors upon their own seeking. Let our system be for affording, not for forcing instruction; for encouragement in every direction, not for prohibition in any. Do not let us degrade what has higher grounds upon which to rest into a mere notice board against trespassers, which any preliminary inquiry, if coupled with the condition of originality, could alone be.

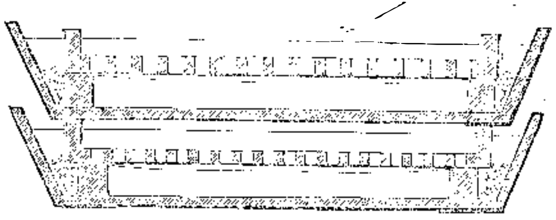
Give inventors all possible information not now accessible; give them all possible liberty, but do not meddle with them until others complain that they have taken what previously belonged to those others. Let relative rights be adjusted as all other rights; self interest will do the rest.

If England expects to maintain her inventive superiority, she must boldly open up every possible source of thought, old or new. She must break up some of the old, worn grooves in which we are now too prone—or, perhaps, too much compelled—to move. Let her, above all, give back to the inventors of the future the vast stock of thought put upon a now useless record by the inventors of the past. It would be like shedding a new light over the scene of inventive exertion.

A New and Simple Continuous Battery.

Professor Bottomley, of the Glasgow University, thus describes a new battery in use in that institution:

A shallow wooden tray, square and with slightly slanting sides, is lined with sheet lead; and this, after being electrotyped with copper, forms both the containing vessel for the liquids and the copper plate of the cell. Copper trays were used at first, but they were soon eaten through by the solution. The lead is not attacked at all. The length of a side of the lead tray is 21 in., and its depth is 3¾ in. In each corner is set a small block of wood 1½ in. high. The zinc plate, which is like a square gridiron, rests at its corners on these blocks. The zinc has parchment paper tied round its lower surface and sides. The cell is filled up with saturated solution of sulphate of zinc, and crystals of sulphate of copper are dropped in, when required, round the edges outside the parchment paper. For connecting these cells together in series, the lead lining is carried over the wooden tray at the corners and down the outside to the under surface of the bottom of it. Here it is soldered to a small squar of thick sheet tin. The cells are piled up one on the top of the other, the tin plates of the second cell resting on the first, and so on. The tin connections—a suggestion of Mr. Varley—are most excellent. Two of these cells are shown in section, Fig. 5. The resistance of each of these cells is on an average 0·19 of an ohm. They are now used at all the telegraph stations where Sir William Thomson's siphon recorder is employed.



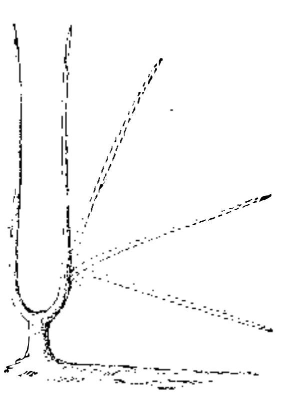
In using these batteries in a laboratory, where they are not perpetually at work, the best way of managing them may possibly be not to charge them with sulphate of copper except when they are about to be used, and only to put in as much as will do the work required. To calculate the quantity is easy; and any small excess might be worked off through a low resistance. We have been keeping them at work almost night and day. They require no attention except to be occasionally supplied with sulphate of copper crystals, and to have the sulphate of zinc that creeps up over their edges wiped away with a cloth.

At present our battery is tested very frequently, generally once in four or five days. The electromotive force and the internal resistance of each cell is determined. We have now had the greater number of the eighty cells in action for three months, and some of them for five or six months. During all that time they have been most satisfactory, the electromotive force of them having remained perfectly constant.

Increasing the Vigor of Growth in Plants.

It has been known for some time that if two branches of a fruit tree be selected, of about the same size and the same upward inclination to the horizontal plane, and one of these be bent downward toward this plane, it appears to lose its vigor, while the other gains in like ratio. It is now announced as the discovery of an ignorant peasant on the Danube, named Hooibreuk, that this law holds good only up to the horizontal position; and that if the branch is depressed still further, and below the horizontal, it becomes characterized by much greater vigor than before, and, in fact, will put out leaves and branches to an astonishing and unheard of degree. But this depends upon keeping the branches as nearly as possible in a straight line, the effect being measurably lost with a considerable curvature. In this case, only the buds which occupy the top of the arc are developed completely, at the expense of the rest which remain in their original condition, contributing neither to the extension of foliage nor of fruit. (The successive positions of the branch are illustrated in the cut.)

Duchesne-Toureace, in communicating these facts to *Les Mondes*, attempts to show the causes which seem to determine so great a flow of sap to the branches inclined below the horizontal line, and thinks that the explanation is to be found in the establishment of a siphon arrangement, by means of which the juice is carried over the bend from the main stem in excessive flow. Be this as it may, the fact remains, as illustrated by an experiment prosecuted by this gentleman. In early spring, when the sap was running in the vines, he took four plants of about the same size, and trimmed them so as to leave one stem to each, these being arranged vertically and obliquely upward, and horizontally and obliquely downward. He then cut off the stems and collected and measured what exuded, and found the amount from the branch inclined downward was more than three times greater than that from the others.



Car Ventilation.—A correspondent of the *Car Builder* calls attention to the fact that the problem of car ventilation is still unsolved. Whoever can invent a simple and effective system for the ventilation of railway cars will be likely to reap a good reward.

Correspondence.

The Editors are not responsible for the opinions expressed by their Correspondents.

Testing Turbines.

To the Editor of the Scientific American:

I have read all the efforts to illuminate the turbine question that have appeared in the Scientific American.

In the last one there are some noticeable points, by R. H. A., on page 228 of the current volume, who puts forth some quite curious ideas in relation to the efficiency of turbines; with some of which I must beg to differ. These differences may not be very important; they are certainly entitled to some consideration as historical facts or well demonstrated theories. It is very true that all engineers concede a difference of percentage with extreme variations of head; but what that proportionate variation in head and percentage is has never been satisfactorily determined. Natural causes are known to modify the efficiency of the same turbine under extremely high or very low heads. The extent to which some of these causes affect the efficiency may be readily computed and proved by actual test. That some turbines work much better under low than under high heads is no doubt true. Whether there are some which work the better under high heads remains to be proved.

That a properly formed turbine will work equally well under considerable variations of head, is certain. The following extract, from the report of some carefully made experiments, proves this beyond a doubt:

Head in feet.	Relative speed.	Efficiency.
11·772	·709 per cent.	·802 per cent.
11·952	·686 "	·802 "
11·995	·730 "	·804 "
12·175	·702 "	·808 "
13·016	·745 "	·804 "
14·084	·731 "	·804 "
14·410	·746 "	·803 "

In these seven experiments, the variation in efficiency is six tenths of one per cent. The variation in head was ·224 per cent, and the variation in relative speed was ·087 per cent. "That more patents are yet to be obtained before the best effects can be had" is quite novel; the utility is less apparent, though by substituting "will," for "can," the truth would certainly be told. It is very doubtful, to say the least, if results higher than have already been obtained depend on patentable devices. It is quite safe to say, that no material progress has been made, in the efficiency of first class turbines, during the last half century. It is now nearly, or quite, fifty years since Fourneyron obtained ·88 per cent from turbines "cast in one piece."

It is very true, in nine cases out of ten, that we "by no means" get what is claimed as the proportion of the whole power of the weight of the water." The philosophers have said that "action and reaction are equal." Many inventors, with more enthusiasm than common sense, have in consequence claimed that water has a double force, impulse and weight; and that it has really twice the power in it, under any given head, that it has ever been credited with. Hence the great variety of contrivances to use the impact, impulse, percussion, or blow of the stream of water upon one set of floats, calling it direct action; whilst upon another set in the same machine, they attempt to use the weight, backward pressure, or spirt of the water, calling it reaction. In this sense, not even 30 per cent of the sum of the forces has ever been utilized. All intelligent persons now concede that the total force of a stream of water is directly as the weight and the fall. It is believed that turbines do not act on the impact or the reaction principle; but that the action is simply a direct, gentle, and gradually increasing pressure upon the buckets of the turbine. How the results of tests can be called speculation, I am at a loss to know. We have all the evidence that any reasonable man ought to ask for. Overshot wheels have actually raised, from mines, 70 per cent of as much water as was required to drive them, the total loss in all of the machinery being 30 per cent Certainly one third of this must have been in the pumping machinery. It has been equally well demonstrated that the overshot has utilized 86 per cent of the total power of the water used upon it. It is, however, no sign that all overshots utilize 86 per cent because one has done so. Nor is it any sign that all Fourneyron or all Jonval turbines utilize 80 per cent, from the fact that their inventors got that result. There are all grades of these famous machines, from 30 per cent ones to 80 per cent ones. Because a small turbine was "accurately and nicely constructed" is no evidence that it was accurately and properly designed for the purpose to which it was applied. The test proves, positively, that this feature was sadly wanting, or else the pumping machinery was defective. It is quite possible that both were ill adapted to the purpose, whereas an hydraulic engine is the most simple and effective method of utilizing the force of a stream of water, to force a portion of the same to a greater hight than the fountain head. A turbine, with the necessary gearing, is quite the reverse of simple when applied to the raising of water.

The similarity between a rotary steam engine and a rotary hydraulic engine is quite discernible; and one is about as effective as the other; but between the turbine and any rotary engine yet before the public, there is a vast and a radical difference, from my point of view. Nor is it the aim of all inventors of turbines to imprison the water until no more work is left in it. In one turbine at least, the water is, as much as is possible, left to its own natural course after entering the turbine, except in regard to its velocity alone. The inventor, in this case, has always allowed at least 8 per cent of the total force to be left in the water, at the instant of leaving the edge of the bucket. His theory is the expansion one for all fluids. The water is received upon the bucket of the tur-