After referring so much to man's doings in connection with mechanical art, it seems almost presumptuous to pass so abruptly to the laws of nature, which act over the immensity of space, as compared with these, the greatest work of man is insignificant. Still, by his ingenuity, he takes advantage of the power and laws of nature in thousands of different ways, and by his skill organises their application into all branches of mechanical art and manufacture. My object in the present lecture is not so much to explain the laws or principles in themselves, but rather to draw attention to some of the more familiar laws, for the purpose of referring to their application, and likewise to some of the various contrivances by means of which man turns them to account. By way of pre-eminence, I select, first, the grandest scientific discovery ever made by man, namely the universal law of attraction, which was revealed to the world by our own immortal Newton, and, strange although it may appear, it will be found that this great law, under its conventional names of gravitation, cohesion, or capillary attraction is constantly in operation in all our busy workshops. With the law of gravitation we are all familiar, in its formation of a dew-drop, or a tear, or that two globules of quicksilver, placed side by side, run together and form one globule. An interesting illustration of the action of this law, upon a small scale, is seen in the manufacture of leaden shot, in which the same law that formed planets into spheres is to be seen in daily operation. The lead is melted at the top of a tower some 200 feet from the ground; the metal is poured into a kind of sieve or cullender, and passes through the holes by gravity; as in the case of rain, so here the metal separates into drops; by falling through the air, these drops lose sufficient heat to render them solid before reaching a cistern of water at the bottom. When lead is employed by itself, for want of fluidity, many of the balls are imperfectly formed, and hence a small portion of arsenic is mixed with it in order to obtain greater fluidity, thus giving the law time to act; for when the lead sets too quickly the perfect sphere is not accomplished—it is more of a pear-shape, but with a certain liquidity each atom is drawn to a common centre into a perfect sphere. Still more instructive is the phenomenon when the metal is too liquid from an over-dose of arsenic, for then, by remaining too long in the liquid state, the little ball requires a whirling motion before it is a solid, and, like our little world, the centrifugal force acquired from its whirling motion throws it beyond the sphere into the form of an oblate spheroid.

So far, we have two illustrations of the law—first, in forming the drop into a sphere; and next, in drawing the drops of lead down to earth; but gravity has yet another office to perform, in separating the good from the bad, and in the assorting of them into their respective sizes. When the spheres are afterwards collected, many of them are found imperfect, besides being of different dimensions. A very simple but ingenious application of the law is employed to separate the good from the bad. They are all run down an inclined plane; those that are pear-shaped run off at the sides; those that are perfectly round acquire such velocity from gravitation sufficient to carry them over certain pitfalls in the way, and so they reach the bottom in safety; but the remainder, that are not so round, do not acquire a velocity sufficient to carry them over the pitfalls, and so they drop through, and along with the other imperfect ones are gathered up to be re-melted. The whole of the good spheres, of all sizes, are then collected and poured into the upper end of an inclined revolving cylinder, having a succession of holes of different sizes upon its outer surface. As this cylinder is continually turning round, gravitation is lying in wait, and the small shot are drawn through the small holes, and fall into a box on purpose underneath; then the next size fall through other holes into another box, and so on until all are disposed of.

The kind of attraction commonly called cohesion is another modification of the same great law. In its usual acceptation it refers to the force by which the molecules and atoms of the same body are held together; but when we bear in mind that the force of gravitation is inversely as the square of the distance of the centers apart, when the particles of the same body are in contact, they may be many thousand times nearer to each other than when separated by the ten thousandth part of an inch. As a rule, in the practice of applied mechanics, the engineer is most frequently called upon to prevent the rupture of cohesion, from the effect of some extraneous force superior to the inherent attraction of its own particles. Still there are many exceptions, and most engineers are familiar with instances of separate substances becoming united from their having been permitted to approach too closely to each other, thus allowing the natural law to assert its superiority; and which it will invariably do whenever it has the opportunity.

It is a fact, well known to those who are engaged with the softer metals, that if two pieces of lead have their pure metallic surfaces laid bare, and then put together with pressure and a twist, they will unite and become as one piece. It is not so generally known that two dissimilar metals will unite in the same manner, say steel, or iron, or brass, with lead. In the manufacture of leaden bullets by compression, where the dies have to plunge into the solid lead, it is found that, after a short time, the steel will unite with the lead, and become one conglomerate mass, hence it is necessary in all such processes to introduce some unctuous matter to prevent contact, and so hinder the law from acting. This cohesion does not take place because the metal lead is soft; it certainly requires less pressure on account of the softness, but it arises from the two metals coming together with pure metallic surfaces while under pressure. The same result may happen with hard surfaces if they are perfectly clean; even two pieces of glass that are made truly flat and clean on their surfaces will join together in the same way. A case occurred with two pieces of hard steel, six inches in diameter. Previous to the introduction of the present methods of taking the thrust of the shaft of a screw propellor in steam vessels, the thrust was received by a fixed piece of steel, a corresponding piece of hard steel forming the end of the shaft; the two came into actual contact, from the absence of oil, water, or other medium, and so became united, the shaft breaking elsewhere. Surfaces so flat, so purely metallic, and with so much pressure, are fortunately rare, but we frequently meet with an approximation to the conditions, and which, for convenience, is usually termed adhesion. Adhesion is usually considered as the union of dissimilar substances, but is this strictly correct? Is not the union between the steel die and the lead just as much the attraction of cohesion as that of the two pieces of lead or steel? The difference of term has probably arisen from the circumstance that when two dissimilar masses are thus united, they in course of time drop asunder; this dropping asunder, however, proceeds from another law of nature, a much more inexorable law than that of attraction, a law which man frequently tries to disobey, but the penalty is invariably inflicted. It is the law of expansion by heat and contraction by cold, and the variable rates of expansion and contraction of the different substances in nature that separates them. When a piece of iron is soldered or riveted to a piece of brass at some definite temperature, all is well, but when the heat is increased, the brass expands more than the iron—then commences the struggle for liberty of action; the elasticity of the materials comes into exercise as a peacemaker, but the natural law will act, by bending the structure, that is to say, the longer piece of brass will form the outside of the curve; then, as winter comes round, the contrary effect is produced, and the brass is the inner ring of the circle; so, when lead is thus united to steel, the greater expansibility of the lead causes it to strive for liberty by a wriggling process, carried on probably for years, until at length the law of attraction is defeated.

There is yet another modification of the great law, which, for convenience, is called capillary attraction. It is that property of liquids whereby they rise in tubes or other porous substances of any kind, even in a bunch of glass threads, of iron wire, ropes, or woods, or even between plates that are near to each other. Now, in this simple process, there are three forces at work, all in obedience to the great law; first, gravitation pulling the fluid downwards; secondly, the attraction that draws the atoms of the fluid to each other; and, thirdly, the attraction of the bundle of fibres, or the sides of a tube that draws the fluid upwards. From this it follows that the smaller the tube, or the closer the bundle of fibres, so the higher will it rise in proportion. All are familiar with this law in ordinary life. The corner of the towel in a basin of water empties the basin; the oil rises in the wick of the lamp; the engineer employs it to oil his machinery by a cotton wick introduced into lubricators; but in applied mechanics it has many varied duties to perform, and its irresistible effect has frequently to be guarded against as well as taken advantage of. When a rope or a piece of wood is subjected to its influence, the bulk of the mass is increased; and in the case of a twisted rope, the fibres are drawn in by the enlargement, and thus the rope is shortened. When a dry wooden wedge is driven into the crevice of a rock the wedge swells and splits the mass. Until a few years ago, all grinding-stones were fixed upon their axles by means of dry wooden wedges, driven into the space between the axle and the stone. After a time the wedges became wetted and swollen, for a while the strength of the stone resisted their efforts, until it became reduced in diameter by wear. Then the natural law, with the aid of centrifugal force from the velocity of the stone came into play and scattered the mass into fragments, at the cost of many a poor grinder's life. In modern arrangements man has become more obedient—he now grips the stone sideways between two discs of iron, thus removing the splitting action of the wedges, and at the same time anticipating and providing for the effect of centrifugal force.

Those who have lived in tents well know the effect of rain in shortening the ropes, and thereby pulling out the pegs by which stability on the ground is maintained; but, it is not so generally known that a very heavy mass, such as the anvil of a steam-hammer, may be raised a short distance without the usual tackle, by simply tightening a bundle of dry ropes over it by means of a long pole, then wetting the ropes, when they necessarily become larger in diameter, and at the same time shorter; by this means any mass that the ropes are capable of sustaining will, in obedience to the law, be made to swing. It is said that when the statue of a celebrated hero was in the act of being raised to its present elevated site, the rope slings had so stretched by the great weight, that the blocks became foul of each other when the statue wanted but a very small distance of being at the required height, so that it might swing over upon the top of the column. The engineers who were engaged in raising it, after exhausting their skill in useless efforts, were about to lower it to the ground as a lost attempt, when an old sailor in the surrounding crowd, who saw their difficulty, and who knew the natural law, called out, "Wet the ropes;" the hint was taken, and produced the desired effect. Knowledge is always power.

The law that governs the pendulum is another kind of example of extensive application in practical mechanics, although even the pendulum law is dependent upon Newton's great law of attraction. The discovery of the pendulum law was made by Galileo, who, next to Newton, was perhaps one of the greatest philosophers who ever lived. We are all familiar with the story, that, while still a young man, he was sitting one day in the metropolitan church at Pisa, through some cause, one of the lamps suspended from the ceiling was set in motion, and, from its great length, continued to swing backwards and forwards for a long time afterwards. He was struck with the circumstance that it took the same time to make the long swing at the commencement when first disturbed, which it did to make the shorter swing just before coming to the state of rest. There were no clocks nor watches in those days, but by means of his pulse he managed to verify the fact, and with further experiments after he went home, fully confirmed and revealed the law of synchronism of the pendulum. That when of equal length, at least within certain limits, when the pendulum is raised at one side by the hand in opposition to gravity, the same amount of work is necessarily bestowed upon it by gravity during its descent which is sufficient to carry it to the same height at the other side, and but for the resistance of the atmosphere, and the friction of the rod, would go on continuously. This discovery may not have seemed of much value at the time, but it has turned out to be of the greatest importance to the world. It is the best measurer of time which man has yet found out. Before many years had passed, it was turned to practical account by Huygens as a clock regulator, a clock being simply a piece of mechanism to count and show the beats of the pendulum in a given time, with a weight to counteract the resistance of the air and friction. This, in time, led to the application of the balance-wheel for watches; for man, once getting hold of a clue, did not rest until he found out that a small spring could take the place of gravitation; for what gravity is to the pendulum, the little spring is to the balance-wheel; both pull to a center of rest, but the work or force then stored up carries it as far the other way; and as a substitute for the weight of the clock, the main-spring is introduced into the watch, so as to overcome its little friction and other sources of retardation. The world had gone on many thousands of years using the plummet, before Galileo's time, but no one had previously observed that it contained the pendulum law, and but for the circumstance that the knowledge fell into the hands of that great man, it is quite possible that no other man might even yet have ascertained it. The steam-engine and water-wheel regulating governors, with which we are all more or less familiar, are but modifications of the pendulum principle combined with other forces, and, to a certain extent, are governed by its laws; and the probability is very great that, but for the knowledge of Galileo's pendulum, James Watt, even with all his unrivalled powers of invention, would have gone off in some other direction, in seeking for a principle on which to construct a governor for his engine. Thus it is that real science is ever making way. A true position once taken is never given up; errors are gradually discovered, and eliminated, and forgotten, but the laws of nature will hold their own to the end of time. During the past 100 years machinery-governors have been constructed on many different arrangements, the greater number of them are on the pendulum principle, but in none of them have we reached the extreme simplicity of the old pendulum. As a rule, man's first efforts in every kind of machinery construction is complex, but, as time advances, the thinking tear and wear of different minds, gradually render it more and more like to the simplicity of nature.

Before leaving the pendulum law, let me refer to another kindred law, that of inertia, which is that property of matter whereby it will continue in its present condition, whether at rest or in motion, unless it is interfered with from without. As this is a subject on which some practical men have unsound views, mostly traceable to the old notion of *vis inertia*, a term still to be found in some books on natural philosophy, artillery and mechanics. There is no such principle in matter as that word implies, the only property is that of passiveness, inactivity, or inertia. Matter is as willing to be in motion as at rest, and as willing to rest as to be in motion; the same power that is required to set it in motion is required to stop it again. This error has affected arrangements in all past times, and it is only of late years that the minds of engineers have begun to shake off the thraldom. The whole principle may be explained by the pendulum. A portion of strength equal to gravitation is expended in raising it; when the ball is set at liberty, gravitation again performs the same work during its descent; if stopped when at the bottom, the same work that was performed by the right hand has to be expended upon the left hand; if the pendulum is not stopped, then the force stored up in it will carry it up until the gravitation resistance balances the previous force of acceleration from gravitation, but the ball itself is perfectly passive, and is without any living principle to influence it one way or the other. It would be interesting to trace the mental working of those engineers who are gradually breaking through the practice that was founded upon a misconception of the natural law. Familiarity with the reversing of railway and marine engines has shown it to be inertia merely that has to be overcome either in setting in motion, in stopping, or reversing, and this accounts for the rapid introduction of coupled reversing engines of light construction and without fly-wheels during the past five years, and nowhere more perfectly than at Crewe, by Mr. Ramsbottom.

Passing to another of the natural laws in connection with the atmosphere which plays a most important part in applied mechanics, we have there a striking example of the intimate relation that exists between science and art. Although this law is apparently inconsistent with gravitation, in that lighter fluids ascend through heavier, as in the ascent of balloons, or the draught in chimneys, yet this law, like that of the pendulum law, is equally dependent on the law of gravitation. It is merely in obedience to that great law that the heavier air of the atmosphere descends, specifically lighter air in the chimney or the balloon is floated upwards. The ship floats on the water because, bulk for bulk, the ship is lighter than the water; so the balloon, bulk for bulk, is lighter than the air, hence it rises in the great ocean of the atmosphere.

In ancient times men were fully acquainted with the raising of fluids, such as water, and of the existence of the air. They even made machines, such as pumps, to take advantage of the air-pressure, yet they had no idea of the laws by which it was regulated; hence it was a blind groping in the dark until the law was understood. It was as well known to the world two thousand years ago as it is to us that water would rise in the pipe of a pump to about 30 feet, but, not knowing the true cause, they invented an explanation, as men do now when they are groping in the dark, and as we constantly are in regard to many things. The explanation was that the water rose in the pipe because "nature abhorred a vacuum." It was in the middle of the 17th century that Torricelli discovered the law, and then all mystery was removed, and we now know why nature abhors a vacuum, or why the water rises in the pump. The story of Torricelli's discovery has been often told and is well known to all, yet is always interesting to the young mechanic. A pump was being erected in Florence; it was deeper than ordinary, and commanded some little attention at the time. During their leisure hours, we can picture the intelligent young lads of that Italian city gathering around the new pump. When it came to be tried, for some reason the water would not come up. We may imagine all sorts of coaxing being resorted to, water poured in at the top to induce other water to follow, but to no purpose, and they were obliged at last to abandon it as a lost attempt. The great Galileo was consulted. He was now a man of mature age, and was considered the greatest man of his time. It is said that after consideration he gave it as his opinion that nature abhorred a vacuum up to a certain height only; but this, I consider, to be a very doubtful statement. The youth Torricelli, who was a favorite pupil of Galileo, did not feel satisfied. He possessed a clear intellect, and in farther reflecting over the matter, it occurred to him that the atmosphere might have something to do with it; that possibly when the pump was worked the air might thereby be exhausted, and that the surrounding atmosphere resting on the surface of the water in the well would thereby push up the water into the empty space in the pump. Still he had only a glimmering idea, when a most happy thought suggested itself. He said, "If the atmosphere has something to do with it, then mercury, which is 13½ times heavier than water, would not rise above 28 inches; if I fill a tube with mercury, having one end closed and the other open, then by immersing the open end in a cup containing that liquid, the mercury will not run out, but remain at a height in proportion to the weight of the atmosphere." The experiment was made, the mercury stood at nearly 29 inches; according to the laws which govern liquids it ought to run down. There must exist an enormous pressure equal to some 34 feet of water column, but by some agency was prevented from running down. What can prevent it from heaving up the liquid mercury in the cup? It must be the equally weighty atmosphere resting on the surface. It was afterwards ascertained that the atmosphere rests on the earth's surface with a pressure equal to 14·7 lbs. on every square inch. No sooner was the law of the atmospheric pressure discovered than it began to yield fruits. Up to this time there was no barometer, nor did Torricelli yet know that he had actually invented one. Before many months the rumour of the new theory reached France. It was the celebrated Pascal who, on hearing of the discovery and the inference deduced from it, made the remark that it might be put beyond all doubt by making the experiment beside a mountain, and, by proceeding up or down, the mercury would rise or fall as the column of air was decreased or diminished. The experiment was accordingly performed beside a mountain, and the result was exactly as had been anticipated. The world had now obtained its valuable instrument the barometer, and this again soon led to other results, and eventually to the invention of the steam engine, which, as originally constructed, was entirely dependant on the pressure of the atmosphere for its efficiency. Before two years the knowledge of the discovery had reached England. Among the first to hear of it was a noble youth, the Honorable Robert Boyle, who longed to make the acquaintance of Torricelli. He went to Italy, and was in time to see the last days of the great Galileo, who died in 1643. But the news of the discovery had spread into Germany. Otto de Querricke, the Consul of Magdeburg, is busy trying experiments with the well-known hemispheres, and is struggling with the invention of an air-pump for the purpose of exhausting them. These hemispheres, in their day, were a great invention, and rendered all the more interesting from the circumstance that it was by means of them that the attention of mankind was first drawn to some of the properties of air. The inventor, Otto de Querricke, had two hemispheres made, about a foot in diameter; he had no air-pump, but by some means managed to get out the air by first filling them with water, and then pumping it out, at the same time taking care to prevent air from getting in. It took the world by surprise. We read that the hemispheres were pressed together so powerfully that six of the emperor's horses were unable to separate them. By the experiments with the air-pump, Otto de Querricke discovered the elasticity of air, and added greatly to the world's store of knowledge regarding the whole subject. During these experiments, he was visited by Robert Boyle, who, by his ingenuity and perseverance, gave to the air-pump, that well-known form in which it has been handed down to us, with the exception of a few recent improvements.

Before twenty years these discoveries began to bear fruit in other directions, for, in a small town in Holland, in the year 1663, we find this knowledge of the pressure and elasticity of air being turned to practical account. At that time the Dutch were the great engineers of Europe, and occupied that place in engineering that we now hold. John Vander Haydon was a great engineer, with considerable practice in the erection of pumps, but, to his frequent disappointment, he found that when he had to give an intermittent motion to water there was constant danger of either breaking the pump or of bursting the pipes, arising from the non-elasticity of the water. Happening to hear of the Torricellian experiment, and also of the doings of Otto de Guerricke, it now occurred to him that he could introduce an elastic cushion of air into the pipes, so that the immediate effect of the piston would be to compress the air, when the air by its elasticity would produce a constant stream of water outwards; this he carried out into practice, and it answered most admirably. Before he was aware, Vander Heydon had really invented the fire-extinguishing engine, and by the end of that year the first fire-engine was constructed, in which the discharge from the pumps went to compress the air in a central air-vessel, the elasticity of the air being the agent to send the continuous squirt of water outwards. Since that time the air-vessel has been applied to every extensive ramification of water-pipes, but the world should not forget that the first idea in modern times belongs to Vander Heydon. I have said modern times, because that great man Hero, of Alexandria, 120 years B.C., had a fountain in his courtyard, constructed on a similar principle.

In this hurried and most inadequate sketch, a feeble attempt has been made to show the relation that subsists between art and science in a small branch of applied mechanics, my chief object being to forward the teaching of the simple principles and laws of nature in every school, and to all the youths who are to become our future workmen, to let them know that there cannot be a practical result of any kind without a fundamental principle, and that before entering the workshop their minds should be well grounded in the unalterable laws on which their work is founded. Such knowledge encourages the mind for practical duties, and prepares it for grappling with the multifarious questions that are continually arising, and will prevent them from falling into practical error.

The simple principles of the mechanical powers, which were so well known by Archimedes, have, by the perseverance of man, during many ages and in many countries, become the refined mechanism of our factories and workshops; yet with all the profound sagacity of his mind, he did not perceive that such simple elements could admit of so many combinations and arrangements. Therefore, in our pursuit after the economic application of natural law, we must not overlook these other natural laws that may not seem now to bear so directly on our industrial operations. Time and study will adapt them all to some useful purpose, by the well-directed thought of a future Watt, or a Stephenson, or a Whitworth.

EFFECT OF MAGNETISM ON TIME-PIECES.

(*From the Waltham Watch Papers.*)

The intention of the present paper is to point out a defect in the construction of time-pieces of every description in which balances are used, and at the same time a source of error in their performance, which has been hitherto little, if at all, suspected, but which, where it occurs, completely defeats all the ends intended to be answered by the application of the above-mentioned ingenious contrivances; and that it does occur very frequently will be made sufficiently obvious by a simple detail of facts supported by actual experiments.

It has been suspected by some and denied by others that the balances of watches when manufactured of steel, as they mostly are, might be in a small degree magnetic, and consequently be disturbed in their vibrations, but that a circular body, such as a balance is, should possess polarity—that a particular point in it should have so strong a tendency to the north, and an opposite point an equal tendency to the south, as to be sufficient to materially alter the rate of going of the machine when put in different positions, has never, I believe, been even suspected. If it had, the use of steel balances would have been laid aside long ago, particularly where accurate performance was indispensable, as in time-pieces for astronomical and nautical purposes. Though I have frequently examined with great care watches that did not perform well, even when no defect in their construction or finishing was apparent, and suspected the balance to be magnetic, yet I never could have imagined that this influence, operating as a cause, could produce so great an effect as I found upon actual experiment; for I did not expect to find that a balance, even when magnetic, should have distinct poles.

Happening to have a watch in my possession of excellent workmanship, but which performed the most irregularly of any watch I have ever seen, and having repeatedly examined every part with particular attention, without being able to discover any cause likely to produce such an effect, it put me upon examining whether the balance might not be magnetic enough to produce the irregularity observed in its rate of going. I took the balance out of its situation in the watch, and after removing the pendulum spring, put it into a poising tool, intending to approach it with a magnet, but at a considerable distance, to observe the effect, while at the same time the distance of the magnet should preclude the possibility of the magnetic virtue being thereby communicated to the balance. I had no sooner put it into the tool than I observed it much out of poise—that is, one side appeared to be heavier than the other; but, as it had been before examined in that particular by a very careful workman more than once, I was at a loss to determine what to think of the effect I saw; when happening to change the position of the tool upon the board, the balance then appeared to be in poise. As there could be no magic in the case, it appeared that the balance had magnetic polarity, as no other cause could produce the effect I had witnessed, and which was repeated as often as I chose to move the tool from the one position to the other. It happened that I was then sitting with my face to the south —a circumstance that led me, in placing the plane of the balance vertically, to put it north and south, and of course the axis east and west, the only position in which the magnetic influence could make itself most apparent, and which will account for the circumstance not having been observed by the workmen who examined the poise of the balance before I did; for, as often as I placed the plane of the balance vertically between the east and west it was in poise, whichever end of its axis was placed toward the south.

Having pretty well satisfied myself as to the cause, I now proceeded to determine the poles of the balance. With that view I placed its axis in a vertical situation, and of course its plane was horizontal; and I was much surprised to find that in that position it possessed sufficient polarity to overcome the friction upon its pivot, for it readily turned on its axis to place its north pole toward the north. Making a mark on that side, that I might know its north pole, I then repeatedly turned that point toward the south; and, when left at liberty, it as often resumed its former position, performing a few vibrations before it quite settled itself in its situation and came to rest, exactly as a needle would do if suspended in the same manner. I was extremely happy that I had observed these effects before I brought a magnet to make the experiment I first intended, as I might, and as others also might have concluded, that the polarity had been produced by the approach of the magnet. I now, however, brought a magnet into the shop, and presenting its south pole to the marked side—that is, to the north pole of the balance, the balance continued at rest; but upon presenting the north pole to the marked place, it immediately receded from the magnet, and resumed its former position whenever the magnet was withdrawn.

No doubt now remaining as to the facts, and being in possession of the position of its poles, I proceeded to examine the effects produced by this cause upon the watch's rate of going. Having put on the pendulum spring, and replaced the balance in the watch, I laid the watch with the dial upward, that is, with the plane of the balance horizontally, and in such a position that the balance when at its place of rest should have its marked side toward the north; in this situation it gained 5^m 35^s in twenty-four hours. I then changed its position so that the marked side of the balance when at rest should be toward the south, and observing its rate of going for the next twenty-four hours, found it had lost 6^m 48^s, producing by its change of position alone a difference of 12^m 23^s in the rate.

It must be obvious to every person, that even this difference, great as it was, would be increased or diminished as the wearer should happen to carry in his waistcoat pocket a key, a knife, or other article made of steel. This circumstance, taken along with the amount of the variation occasioned by the polarity of the balance, was fully sufficient to produce all the irregularity observed in the going of the watch. I then took away the steel balance, substituted one made of gold, and found it as uniform as any watch of the like construction. Steel balances being commonly in use, and on that account easiest to be procured, and being on many accounts preferable to any other, I was unwilling to abandon them entirely, but resolved to take the precaution of always trying them before I should apply them to use. The mode I adopted was, to lay them upon a slice of cork sufficient to make them float upon water, and I was in hopes that out of a considerable number I might be able to select sufficient for my purpose; but, to my surprise, of many dozens which I tried in this manner, I could not select one that had not polarity. Some of them had it but in a weak degree, and not more than one or two out of the whole quantity appeared to have it so strong as the one which gave birth to these experiments and to the present paper, which is perhaps more prolix than could be wished; but the subject appeared to be not uninteresting, and I hope the remarks I have offered will be not altogether useless, as everything that can tend to add to the perfection of time-pieces, to remove any cause that operates against their perfection, is of some importance.

THE OPHTHALMOS.

The Ophtalmos, patented by the Rev. John A. Scott, in February, 1868, is an automatic magnetic photographic camera, to be attached to a small balloon and elevated without the operator to any height above the earth's surface, when, by a clock, working on a lever, in one form, and by an electro-magnet drawing the lever, in the other form of the invention, by the revolution of a disk at the lower end of the pendent instrument, the camera is opened and then shut, and the photograph of the subjacent surface of the earth is instantly taken. At the same instant that the revolving disk, operated by a coiled spring, opens the camera, the magnetic needle is fixed in its position by a mesh of wire that is thrown down upon it; and when the apparatus is drawn down by the cords, the picture is found taken, with all the points and bearings of the compass.

This invention will be of use in several important departments of science and art. The inventor claims that—

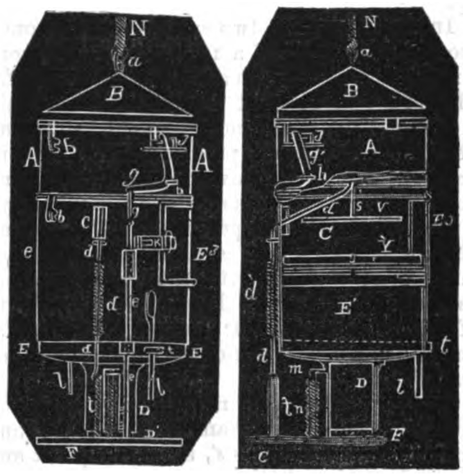
It will enable man to obtain a bird's-eye view of the earth's surface around him, and see objects, accidents of ground, ravines, fields, woods, &c., beyond the horizon of his vision, when even occupying very elevated stand-points on the earth's surface.

This invention will enable the buyer and the seller of land to have accurate photographs of the lands, houses, fields, roads, streams, &c.

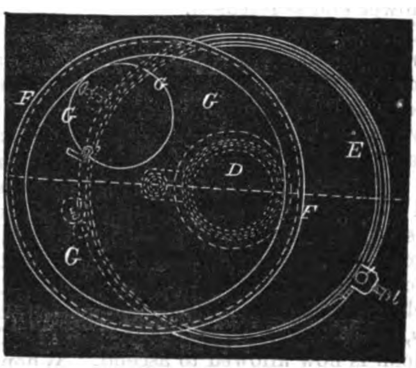
The instrument may also be of use in the explorations of the shoals of the sea-coast, estuaries, and rivers that empty into it.

If the reader will imagine a balloon suspended in the air with a camera, lens front downwards, he will have an idea of the Ophthalmos. An ordinary balloon is used, but the camera used will need some description to make it understood.

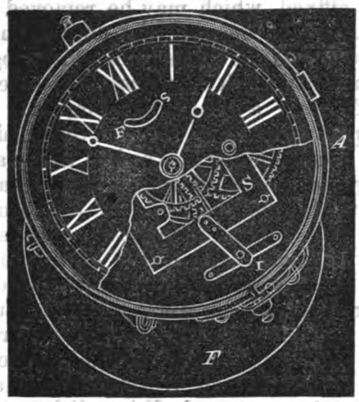
The body of the camera is cylindrical. Within its upper part, A, is a clockwork, which gives the time of day, and also serves as a means of automatically making and closing the exposure of the plate. Below this is a chamber, C, with a semicircular opening closed by a door, E³, to which latter a circular case is affixed, which may be removed from its chamber by opening the door. The top of this case, Y, is marked off with degrees and provided with a magnetic needle, Y′, thus forming a magnetic compass. The lower part of this case receives the sensitized plate. Surrounding it is a ring, also marked in degrees, corresponding to and arranged opposite to the degrees, on the compass above it. V is a wire-netting suspended from the hook S′ by means of the rod, S, which netting is dropped upon the needle of the compass, arrests it while the exposure is made, and indicates the magnetic meridian of the place represented by the picture. D is the lens-tube, and D 1 the lens, adapted for instantaneous work, F is a disk eccentrically secured in a plane at right angles to the axis of the lens; G is a circular plate applied to the bottom-side of the disk so that



it will rotate freely. Through this plate, G, is an opening just the same size as the



opening through the disk F, or it may be larger. To the axis of this plate G, a rod, *m*′, is secured, which passes up through the disk F, and is guided by an arm, *m*, projecting from the lens-tube.



A spring is coiled round this rod, so that when turning the plate G about its axis the spring is wound up.

In the disk F are two small openings, one receiving the end of a rod *e*, and the other for the loop *f*, which is attached to the rod *d*. The rod *e* is allowed to receive a vertical movement, and is attached to one arm of a bent lever *g*, which is pivoted at *h*, the other arm of which lever extends upward to an oblong opening, *j*, so as to be acted upon by a lever *i* at the proper time of taking a picture. The lever *i* is pivoted, *s*, and its inner edge engages with the minute-wheel as shown in Fig. 3, so that by the movement of this wheel the lower arm of G′ is raised, and the end of *e* drawn out of the hole in the disk F.

The rod *d* passes through eyes, and is so bent as to enter the chamber C through an opening *c* and extends *s*′, at which point an eye is formed upon the rod *d*, through which the hook S′, passes, as shown in Fig. 3. The rod *d* is drawn upward by a spring *d*′, when its lower end is released.

To operate with the instrument, G is turned round, and the end of *e* inserted through F far enough to arrest G with the lens covered by it. The loop *f* is also drawn down and attached to the tongue-piece in a hole made through F; V is then hung upon the hook *s*′, the sensitized plate introduced, and the focus adjusted. The instrument thus adjusted is attached to the balloon, and when everything is ready for its ascent the lever is set so that the minute-hand of the clock will at a certain time operate upon the lens, and thus release the plate G. The balloon is now allowed to ascend. When G is released the spring *m*′ will cause it to move, expose the plate, and cover the plate again. At the same time a projection on the side of G detaches *f* from its hook, and allows the spring *d*′ to detach the netting V from its hook S′, thereby causing the netting to fall upon and hold the needle Y in the position which it assumed before the picture was taken. A ball or flag is attached to the instrument in such a way that it will drop to the earth the moment the plate is uncovered. After the exposure is made the balloon is drawn down, the plate removed and treated as all plates are that are taken down or under the earth.—From the *English Mechanic*, the proprietor kindly lending the wood-cuts.

ENAMELS.

The fine enamels of trade are generally prepared by fusing at high temperatures, silica, oxide of tin, and oxide of lead, and spreading the mixture over the surface of a sheet of copper, of gold, or of platinum.

The objections to these enamels are, in the first place their high cost, and, secondly, the impossibility of giving them a perfectly flat surface.

Mr. E. Duchemin has advantageously replaced them by the following economical and efficient compound: Arsenic, 30 parts by weight; salpeter, 30; silica (fine sand), 90; litharge, 250. This is spread on plates of glass of the required shape and size, care being taken, however, that the kind of glass employed be not inferior in point of fusibility to the enamel.

Enameled glass prepared from the above substances may be drawn or written on as readily as if it were paper, and in less time than one minute the writing may be rendered indelible by simply heating the plate in a small open furnace or muffle.

Drawings, autographs, legal acts, public documents, historical facts and dates of importance, labels for horticultural purposes or destined for out-of-door exposure, coffin plates, signboards, show case signs, etc., may thus be cheaply made, which will resist atmospheric influences for ages.

First class photographs, either negatives or positives, may be taken on such enamels without collodion, by using bitumen, or citrate of iron, or perchloride of iron and tartaric acid, or bichromate, or any other salt.

A good solution for this purpose is, water, 100 parts by weight; gum, 4 parts; honey, 1 part; pulverized bichromate of potash, 3 parts. Filter the liquid, spread it over the enamel, and let it rest, after which:

1. Expose it to the camera.

2. Develope the image by brushing over it the following powder: Oxide of cobalt, 10 parts by the weight; black oxide of iron, 90 parts; red lead, 100 parts; sand, 30 parts.

3. Decompose the bichromate by immersion in a bath formed of: Water, 100 parts by weight; hydrochloric acid, 5 parts.

4. Wash it in clean water and dry it.

5. Vitrify the proof on a clean piece of cast iron, the surface of which has been previously chalked. One minute will suffice for indelibly fixing and glazing the photograph, which must be carefully and slowly allowed to cool.

Photographs on enamel of any size, taken in this manner, are perfectly unalterable under all atmospheric conditions, and may consequently and aptly be called "everlasting photographs."—From the *Scientific American*.

SILVERWORK.*

By P. A. Rasmussen.

At first sight it would perhaps appear that as silver is, strictly speaking, about the same price all the world over, the cost of the material of which silver ware is made could not have any great influence on the relative price of the work made by different countries. Customs or laws have, however, established different qualities or alloys of silver in which the manufacture is carried on. These vary greatly—from 950 parts of fine silver in 1,000 parts, which is the French standard, down to 700, or even less, in some parts of Germany, making, of course, a great difference in price. But few countries have any really well-organized system of controlling the standard of work; some have regulations, but do not enforce them. In France, both gold and silver are subject to compulsory control, to the great advantage of the trade. Here, in England, silver is also subject to control, and bound to contain 11 oz. 2 dwt. of fine silver in the pound troy, equal to 925 parts in 1,000; but, with a strange inconsistency, gold is not so subjected, and the consequence is that gold objects are frequently advertised as being "fine gold," "solid gold," &c.; which do not contain perhaps a fourth or a sixth part of gold. It would no doubt be to the great and permanent advantage of the trade, as well as of the public, to regulate the controlling of all gold work, similar to what is done with silver work. In France the introduction of stringent laws, that gold must not be worked of a less quality than 18 carat, was followed by an astonishing increase of manufacture and of exports. Some countries, for instance the United States of America, have no regulations whatever—neither optional nor compulsory control; each manufacturer works in the quality best suited to his class of customers, and marks it himself, whether correctly or not depends upon his conscientiousness. It is needless to say that this is very unsatisfactory.

I append a table, showing the standard of the silver work of the different countries, as far as I have been able to ascertain:—

TABLE

Showing the standard of the silver work manufactured in the principal countries; some of these allow more than one standard to be used, and the difference is indicated by the marks affixed to the work by the controlling authority.

Fine silver = 1,000.

Austria	938
,,	812
Bavaria	938
,,	812
Belgium	833
Denmark	827
England	958*
,,	925†

* Britannia silver, little used. † Sterling silver.

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* In the Tenth Volume of this Journal several Reports by Artizans on what they observed at the Paris Exhibition of 1867, and at the Foreign factories and workshops which they visited in reference to the special industry in which they were engaged, were reproduced from the entire reports as published in one large volume by the *Society of Arts*, under whose auspices and assistance the scheme was carried out. It was believed that these reprints would bring much valuable information before a large section of the horological and kindred trades, which otherwise might not reach them. The cost of the Society of Arts' volume is but half-a-crown, an insignificant sum for such a large mass of printed matter. Nevertheless, comparatively few artizans could afford the time or would care to peruse the whole of the reports, while there is reason to believe that all would gladly read those which had reference directly or indirectly to their own calling. We know that those so brought before our readers already have been warmly welcomed, and it was our intention to have exhausted them so far as they appear to possess immediate interest for us. Circumstances however compelled us to postpone our purpose which we now resume. In the meantime the Editor has read the whole of the Reports, which are certainly very interesting and instructive, and with scarcely an exception they greatly redound to the credit and abilities of the workmen who have penned them. During this perusal he has made a select number of extracts, which will be laid before our readers from time to time. In each case reference must be made for the complete report to the original source.

France	950
,,	800
Holland	938
,,	833
Italy	812
Portugal	845
Prussia	750
Rome	875
Russia	750
Spain	750
Sweden and Norway	827
Switzerland	875
,,	833
,,	750
Wurtemburg	812

While on the subject of the quality of the silver we may also notice the duty upon it, as this is generally paid at the time the control mark (hall-mark in England) is affixed. In England, the enormous duty of 1s. 6d. per ounce is levied, a small drawback being allowed if the work be sent to the hall in an unfinished state; in France it is 12fr. per kilogramme, or about 4d. per ounce, and it is less in many places. Comparing London to Copenhagen, we see that an ounce of sterling silver, including duty, is worth 6s. 9d., while an ounce of the silver of which the Danish work is made, containing about 830 parts fine in 1,000, is worth 4s. 6d., an important fact to remember when the price of silver work in the two countries is compared.

Among other materials used in the silver trade, and tending to affect the cost of the work, are gas and charcoal; the latter very expensive in England, and dearer than on the Continent.

Machinery is not employed to any considerable extent in the manufacture of silver work, if we except certain specialities, such as spoons and forks; and even of these many are still made by hand, although the ornaments on the handle are generally produced by stamping, or by letting the object pass between rollers in which the pattern is cut. Much common work made in Germany is also stamped, such as we saw in the objects sent from Berlin; but in the production of silver work of a high character, machinery performs but a small part. Large and expensive pieces of silver work are in most instances designed to illustrate some particular subject in connection with the persons for whom they are being made, or to whom they will be presented, and may perhaps never be repeated, so that the principal reason for using machinery, which is to produce a multitude of the same articles cheaper than can be done by hand, does not exist here. Among processes tending to economise labor, I found in Paris the process of "spinning" extensively employed in all the ateliers I visited in our trade; and it is likewise in general use in Germany and Denmark.

The process of spinning (repoussé sur tour) consists in "raising" the work from a flat plate to the form required, over a chuck on the lathe, instead of by the more laborious method of hammering. It was first introduced at the time when the manufacture of plated work commenced, perhaps some forty years ago, or rather more. The silver outside the copper being very thin, the removal of the unevenness and marks left by the hammer was likely to take the silver off in places and expose the copper; by spinning, on the contrary, it is possible to get a smooth, uniform surface, as the raising is done by means of well-smoothed and polished steel tools. Since electro-plate has taken the place of the original plate, and the work is more often executed in brass, or German-silver, than in copper, and plated after being hammered instead of before, spinning has to some extent been superseded in that branch, by stamping the work into its shape. The untractable nature of German-silver (or nickel silver) renders it less suited for spinning than the pure copper; but for such good quality of silver as is used in France and England the process is well adapted. In Christofle's great manufactory, I found that even very large objects, such as dish-covers, were spun, both oval and round, the lathes being moved by steam power. M. Hugo, a manufacturer of good dinner and tea services, also employs spinning to a large extent: all the bodies of the different pieces, coffee and tea pots, sugar-basins, &c., were spun; some of them were 7in. or 8in. high, with large bellies and long narrow necks, yet they were spun in one piece, over a wooden chuck, made, of course, of many pieces, to enable its being taken out when the work has received its form. Where a great number of objects are expected to be wanted of one pattern, the chuck is sometimes made of brass, which, of course, lasts longer than wood; but generally good hard wood answers all necessary purposes. The objects spun were considerably lighter than English work is usually made; but M. Hugo informed me that both for France and for exportation lightness was required, and that he, in fact, had difficulty in getting the work light enough. Sets, consisting of coffee and tea pots, sugar-basin and cream-jug, weighed 2 kilogrammes, or sometimes under, and were sold at a price considerably below what is paid in England.

Soldering is done in Paris, as in England, by means of gas, the supply of which seemed scarcely so large in quantity as it generally is in English workshops. In Christofle's place, the necessary atmospheric air for the soldering-gas was furnished by a blowing-machine, saving the workman the operation of treading the bellows, which, in cases of soldering large pieces, taking a long time to get hot, produces considerable fatigue, and even nervousness.

English work is generally well polished; in many continental countries burnishing, of necessity, takes the place of polishing, on account of the silver being of an inferior standard. To give this the appearance of fine silver, an artificial white surface is produced, by making the work red-hot, in which state the copper in the outer portion of the silver becomes oxydised, and this copper oxyde is easily removed by leaving the work a short time in some weak acid, generally diluted sulphuric acid. Thus a very thin coating of fine silver remains on the surface, which may be increased by a repetition of the same process; but is still so thin that the use of the grinding powders, rottenstone and rouge, used in polishing, would soon take it off and expose the natural color of the material; it is therefore necessary to brighten it by rubbing the surface with bright steel burnishers, generally finishing with a highly-polished bloodstone; but on large plain surfaces the effect is very inferior to that produced by polishing.

One of the most important questions affecting the workman, and consequently also the work, is that of his education, both general and special. Leaving the first as much as possible aside, as beyond my produce, and confining my inquiry and remarks to the state of special education, I must own that in England the means of artistic and technical instruction or education within the reach of a workman are lamentably deficient compared with some other countries. Much has certainly been done of late years by the Schools of Art at South Kensington, and by those in connection with them all over the country, and facilities offered for instruction in drawing and modelling which did not exist before; but valuable as they are, I think that the instruction given is more calculated for art-designers and draughtsmen than for workmen, who, after having received a knowledge of elementary drawing, should have opportunities of a more special training, according to the business in which they are engaged.

Taking my own trade as an instance, instruction in engraving, chasing, turning in wood or metal, spinning, enamelling, and some chemistry, so far at least as to understand the properties of the metals and acids, ought to be within the reach of every young workman, besides drawing and modelling.

There could, in my opinion, be no more legitimate way of using some of the great means at the disposal of many of our old and wealthy City companies than the encouraging and assisting schools where the apprentices in the trade with which the particular company may be connected could receive a thorough artistic and technical training. A few hundred pounds annually would go a great way, and how little would that be in the total sum expended by them? Their wealth has been made in connection with a trade; and now we find them, with very few exceptions, not doing anything at all for the good or advancement of that trade.

It is, of course, during the period of apprenticeship that this instruction should principally be received; and here I would observe the fact that this period is in England longer than in almost any other country, seven years being the usual term, sometimes in reality much longer, as a boy is often taken into the shop at the age of ten or eleven years, when he ought to be at school and at play, and remains, of course, until he is twenty-one. In France I found the term varying in our trade from three, four, to five years, the latter being the maximum period, and the one adhered to by most continental countries. It begins at the age of fourteen, and finishes at nineteen. The young workman then frequently travels for a couple of years—an excellent way of improvement, very rarely resorted to by English workmen, in our trade at least.

SILVER-CHASING.

By R. E. Barrett.

The French chaser seldom uses a mat, as we English ones do; but instead he uses tools of his own making, with fixtures on them to suit his own taste. The casters are a more careful class of men than our own. This is a great boon to the chaser, for he is consequently enabled to repair his work in a better manner than we are, and quicker also. Very little thickness-work is done in France; they core-cast instead.

As to French workmen's tools, rifflers are very much used, and the tracers are smaller and more numerous than with the English artisan; and their surface-tools are paid great attention to. The patterns on them are so as to represent nature as much as possible. A large number of punches are used in work, such as stars, leaves, and geometrical patterns. There are a number of gravers used also, and the drapery of figures is frequently shaded with a sharp-pointed tool; a very coarse mat is used in representing velvet drapery, and the matting is partly erased with a punch or riffler, which gives the furry, soft surface of the velvet. Horses are seldom matted with a hair tool; instead, they use a smooth flesh tool. In working up their draperies, they are careful not to use the tracer, and a planisher is deemed a safer implement when a fold in the drapery is under-cut on both sides; but in the hair of the human head there is a tendency to make it too woolly, by putting too many frizzy holes in it; and if they were to keep it broader in surface it would be better.

Adjusting of Work.—Pitch is more sparingly used. They have a new invention, as follows:—Two holes are drilled through their bench; underneath there is a kind of vice, which tightens the strap of leather that they pass through the holes. This does away with the use of pitch, and the artisan is enabled to do away with so much moving of his work, which is a loss of time, and makes work come more expensive. The French artist is more kind and obliging to the worker than ours, and the chaser is, of course, better enabled to carry out his ideas.

Bronze works are carefully cast, and merely repaired at the seams and any other parts that may have come bad in the casting. Some of the French chasers are very good draughtsmen, and many of them model in a small way. A deal of piece-work is done, and the wages of the men average from 30 fr. to 50 fr.; but it is only the very clever hands who get 50 fr.

HAMMERED IRON.

By William Lethbren,

Art-metal Workman.

As far as I am able to judge, the French excel in taste and effect, but I do not consider them more skilful as smiths; in fact, I think the English excel in hammered iron-work. There is a great difference in the design. The French make their work strong and very effective, but the ornamentation, being of thin sheet-iron, is light and elegant, but forms a separate part from the other portion of the work, and consequently must decay very soon; another fault is that, being thin iron, recourse must be had to riveting or brazing. To weld iron so thin to a larger substance would be a difficulty, if practicable at all. If iron-work is to last a long time, it must be welded together, or worked from the solid bar; then the leaves can be made sufficiently strong to last for a number of years. I think a good design should allow of this being done, and I think, in England, good designs do so.

The skill of the smith is displayed in uniting the parts of a piece of iron-work, so that the different leaves and other parts, when completed, form a whole, blending one with the other. Then we get use, durability, and ornament combined. This, the older smiths made their study, and it should be our aim to excel them; in this class of work, the workman must not only be practical, but have a knowledge of design and drawing. In this, as a rule, the English workmen are behind; for we may find many a good smith, but, having no knowledge of drawing, he only destroys the good effect intended by the designer.

I think the schools of art have done much toward the improvement of the mechanic, but few avail themselves of the opportunity. The French have an advantage in this respect; the master of an apprentice is bound by law to give him two hours a day for education; and the class of schools formed for such have a peculiar advantage, inasmuch as the artisan is invited to bring specimens of work of whatever kind, and prizes are awarded, at certain times, to those that excel. In this respect the French are far before the English.

In France, knowledge is at a cheaper rate than in England; when the French workman is at fault for want of some hint, he is at once relieved by applying to his school.

In England it is often found that men work for years doing work the wrong way for want of some knowledge, which is known to only a few, and which they jealously keep secret; this is, no doubt, the reason why progress is slower here than it otherwise would be.

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