the casks by means of ropes passing around the lateral joists (Fig. 8). Finally, two cross-pieces are added to the longitudinal joists. The raft thus prepared is finished by filling in the spaces between the casks with such floatable objects as are found on board, and nailing down planking longitudinally. Stanchions are then placed between the

Perry's Raft (Fig. 4) is composed of three cylindrical bags, A, of strong rubber cloth, pointed at the ends, and bands of cloth, B, two feet wide, connecting them together throughout their entire length as well as to the framework. Each cylinder is provided at one end with a tube, J, by means of which it is inflated. The bags

FIG. 2.—GRANDIN'S RAFT AS ARRANGED FOR THE PACKET-BOAT "EMPRESS EUGENIE."

side planks and joists, and to these are lashed oars and studding-sail booms. It will require about 20 men to launch the apparatus, which weighs about 2,500 pounds, and the platform of which is about 14 by 17 feet. The preceding description applies to the Grandin raft in its simplest form. The raft constructed on board the packet-boat *Empress Eugénie* possesses certain features which tend to consoli-

FIG. 3.—SIDE VIEW OF THE SAME.

date it more, but which are not absolutely essential (Fig. 2). It is entirely covered with tarpaulin, serving as ballast, and also to deaden the shock of the waves on the casks situated at the ends of the raft. The space between the casks is filled in with triangular pieces of wood, which tend to keep the latter from rolling; the same result, however, is reached by gouging out the joists so that they fit the sur-

FIG. 4.—PERRY'S RAFT.

face of the casks. It often happens in case of accident to a ship that the sea is calm and that there is no need of hurry; in such cases a mast and sail may be rigged up (Fig. 3),

having been inflated and laid on the deck, the framework is placed upon them and firmly lashed to them by means of marlines passed through the bands of cloth. The framework is composed of five flat cross-pieces, D D', connected together by two tie pieces, N N, and is so arranged that it may be folded up when not in use. Two tholes are fitted to each tie piece; and one is also placed on a triangular frame projecting out behind for the steering oar. The advantage of this raft is that it is neither heavy nor cumbersome; six men can carry it. It can be inflated and put in the water in 15 minutes, or in 30 minutes at the most in bad weather, and no tackle is needed in passing it over the sides of the ship. It will accommodate forty men, but when the sea is very rough, twenty-five is about all that it will carry with safety.

ECONOMY OF FUEL.

MR. EMERSON BAINBRIDGE read a paper before the British Association on an experiment made to ascertain the cause of the difference between the quantity of heat in fuel and the quantity which is utilized in the work done by a steam engine. He said that the most economical mode of producing and using steam power formed a question of special interest at the present day for engineers, this leading to the problem as to the scope that might exist for the utilization of the large margin of loss in the difference between the heat contained by the fuel and the small percentage of such heat which is represented by the work actually performed by a steam engine. Only 11 per cent. of the actual heat power contained in the fuel was utilized, and though a large proportion of that loss could never be overcome, the importance of the inquiry was evidenced by the fact that every one per cent. gained means in the consumption of this country alone a saving of about half a million tons per annum. About fifty million tons were annually used in the production of steam, which was about 37 per cent. of the whole output. The coal used in dwellings, great as was the waste, was more fully utilized than when it was used in any other way, thus 13 per cent. of the heat actually possessed by fuel was given off in an open fireplace. As an instance of the small amount of heat utilized, it was stated that to produce 31b. of steel 7 lb. of coal were required. The author then gave the results of an experiment he had made with the winding engine and boilers of a small colliery, such plant being nearly 30 years old. Some of the improvements which might be made with a view to promoting economy of fuel were the fixing of boilers of an improved construction with a minimum thickness of plates and a maximum area of heating surface. Special attention should be paid to the manner in which air is admitted to the fire and to the working of the damper. The air in the fire grate should be so intermingled with the gases from the fire as to enable a minimum quantity of air to be used; the application of such form of fire grates and such mode of firing as will enable the cheapest quality of fuel to be used; the complete covering of all exposed surfaces; where water is scarce the application of the best form of water-heater; where water is plentiful the adoption of an improved form of condenser; steam jacketing of the cylinder and mechanical accuracy in the construction of the engine; the application of the system of variable expansion when the work done by the engine varies; in case of winding engines, the adoption of drums of varying diameters; as a general principle, the use of steam at a high temperature. In order to have the greatest possible difference in temperature between the steam when it reaches the cylinder, and when it has done its work. In the application of such improvements to ordinary steam engines, the saving in working cost must, of course, first be considered, and in the adoption of all such means of promoting economy as have been alluded to it may be confidently asserted that the saving in working cost will, as a rule, wipe off the extra first cost incurred in a very short time, since the saving effected will probably vary from 50 to 150 per cent. per annum on the first cost.

RAIN AND TWINKLING STARS.—Pursuing his recent researches on the scintillation of the stars, M. Montigny shows, in a note to the Belgian Academy, that the following conclusion may be accepted: In the twinkling of the stars which show the colored rays, when the blue tint predominates, or is found to be in excess, rain may be expected, if it has not already come. The more predominant the blue the greater the probability that the rain will be persistent and plentiful. It is supposed that the predominance of the blue is owing to the absorption of other colored rays in passing through moist layers of the atmosphere. On the same principle the blue tint of distant mountains indicates rain.

ANTI-FIRE CONSTRUCTION.*

By R. G. HATFIELD, of New York.

ONE of three indispensable requirements of architecture is stability—permanence.

And yet, of all the buildings ever erected, how few still remain!

Even that achievement of engineering skill, the Eddystone Lighthouse, which has bravely resisted the power of the Atlantic for one hundred and twenty years, is at last undermined and must fall.

The elements in their unceasing action sooner or later triumph over the proudest works of man.

Of the elements at work in this destruction there is none so active, so successful, as that of fire. With what fiendish relish does it lick up the combustible, and ruthlessly tumble the residue in shapeless ruin! History teems with its work of desolation. The cities of the Old World have all sadly suffered by its ravages: I will mention only one.

The great fire of London, in 1666, burnt for three days, destroying 13,200 houses, including many fine public buildings. The loss by this fire, if computed by present values, would amount to at least \$100,000,000.

The city of New York has suffered by at least three great fires. One in 1835 destroyed six hundred warehouses, which, together with contents, were worth \$20,000,000. Another in 1839 destroyed property to the amount of \$10,000,000, and a third, in 1845, destroyed three hundred stores and dwellings, valued at \$6,000,000. Charleston in 1838 suffered by a fire which destroyed 1,158 buildings, covering one hundred and forty-five acres. Pittsburgh in 1845 lost 1,000 buildings by fire, valued at \$6,000,000. Albany, N. Y., in 18—lost in steamboats and buildings \$3,000,000. St. Louis in 1849 lost \$3,000,000 in steamboats and buildings. Philadelphia in 1858 lost three hundred houses. In 1845 two-thirds of the city of Quebec, comprising 2,800 houses, was swept away by fire. The city of St. John, Newfoundland, repeatedly damaged by fire, was nearly all destroyed in 1846, when 6,000 people were rendered homeless. Troy suffered severely in 1862. Portland in 1866 lost \$9,000,000, including the loss of 1,600 buildings. Chicago in 1871, and Boston in 1872, were devastated to the extent of more than \$200,000,000; and quite recently a devastating fire has almost entirely destroyed the city of St. John, New Brunswick.

But these marked fires do not alone measure the work of destruction: much is due to the smaller fires, which make up by their frequency what they lack in proportions. Constantly at work, little by little, year by year, the aggregate of ruin they accomplish is fearful.

A record kept by the *New York Insurance Chronicle* shows that the losses by fire in the United States and Canada in 1876 was \$75,000,000, and in the previous year it was \$86,000,000. This record is doubtless trustworthy, as far as it goes, but I am assured by competent authority that the loss during the last ten years has not been less than \$100,000,000 per annum, not including the two extraordinary fires of Chicago and Boston.

What a fearful havoc! Is there no remedy?

The losses in the United States and Canada during the last twenty-five years aggregate an amount which would have sufficed to have rendered all the buildings approximately fire-proof.

A few figures will show this: The United States census for 1870 gives the value of the real estate of the country, but does not give the value of the buildings separately. This, however, may be approximated. From an estimate made upon the property within certain limits of the city of New York, the value of the buildings was found to exceed considerably the value of the ground. The buildings in the rural districts, however, are of much less value than the land, perhaps not half. A fair average for the two—city and country—would perhaps be, to estimate the value of buildings at one-third of the whole value of the real estate.

The census for 1870 puts the value of the real estate at about \$9,000,000,000, one-third of which (if this be the proper portion), or \$3,300,000,000, then, is the value of the buildings.

This result may be tested by estimates upon another basis: It is shown in the last Report of the National Board of Fire Underwriters, p. 27, that the insurance effected during the last five years averages about \$5,170,000,000 per annum; and it is shown by the records of the *New York Chronicle* that not more than half of the losses by fire are covered by insurance; hence the \$5,170,000,000 insured is only half of the insurable property of the country; or, that the value of the property of the United States and Canada, liable to loss by fire, is not less than \$10,340,000,000. This is the value, not of the buildings alone, but of the buildings and their contents. To ascertain what portion of this is invested in buildings: It is shown by the New York Board of Fire Underwriters in their last Report, p. 23, that in an average of the losses for the past eighteen years, the portion on buildings was about one-third of the whole. Taking this as authority in the matter, one-third of \$10,340,000,000 is \$3,447,000,000 for the value of the buildings in the United States and Canada, which cannot be far from \$3,300,000,000 for the United States alone, as before shown. Of the \$100,000,000 annual loss, one-third may be taken as that which was invested in buildings, and, had the buildings been of a character to resist the flames, a large part, perhaps two-thirds of the loss upon their contents, would have been saved; thus one-third in buildings and two-thirds of two-thirds, or four-ninths of the contents, or together seven-ninths of the whole loss, could have been avoided by having more perfect buildings; or, of the \$3,447,000,000 invested in buildings, there is an annual loss of nearly \$78,000,000 due to deficiencies in buildings. This is more than two per cent. of the value of the buildings, an amount which would in twenty or twenty-five years be ample to render all our buildings approximately fire-proof, and would not only save more than three-fourths of the present loss in material, but that which is caused by interruption to business, and, in many instances, avoid the loss of life and consequent distress to survivors.

Painful instances of loss of life by fire through deficient buildings are still fresh in our memories. The Brooklyn Theater and the St. Louis Hotel cry aloud for reform in building. Whatever may be said of the inexpediency of expending money upon ordinary buildings to avoid damage by fire, there certainly is no good reason why, at whatever cost, places of public resort should not be made safe. As life is more precious than money, so no money should be considered wasted which is required to protect life.

It was lately shown in the Chicago *Investigator* that no less than one hundred and fifty-six theaters have been burned in the United States since the year 1800, and of these, one hundred and nineteen were burned since 1850. Similar state-

* A paper read before the American Institute of Architects.

ments, though perhaps not quite so disastrous, might be made of hotels and other public buildings. The government of a country should be held responsible for life sacrificed in this manner, as well as for those who die by neglect of sanitary precautions. The owners of buildings of public resort should be compelled by rigid law to render their property secure from destruction by fire.

In the construction of buildings the materials most in use are brick, stone, iron, and wood. Brick, above all others, is that which possesses fire-resisting qualities in the largest degree. It has been in use from the earliest ages; it is prominent among the materials of ancient buildings.

The Pantheon, the only entire antique building of Rome, is of brick. The marble with which the brick walls were incrustated has long since disappeared. The metal which covered the roof was stripped off for other use. The only opening for light, the eye of the dome, nearly thirty feet in diameter, has been uncovered, exposing the interior to every storm, and during the nineteen centuries of its existence it has been subject to repeated conflagrations resulting from the wars which so often desolated Rome; and yet, through all these vicissitudes, the Pantheon remains in such good condition to-day as to serve as one of the churches of the city. Its durability, however, is due not alone to the character of the material of which it is constructed, but to its form, the strongest known, a cylinder.

Stone, though inferior to brick, is far superior to iron in its fire-resisting qualities. Granite when exposed to intense heat will crack and splinter freely; marble is quickly reduced to lime; sandstones disintegrate. Only those stones which are of volcanic origin may be safely trusted in the fire.

The extensive use of iron as a material of construction is of recent date. Fifty years ago it was but little used. One of the principal reasons for introducing it was its fire-resisting character. Gwilt, in his *Encyclopedia*, page 494, article 1767, edition of 1842, in speaking of iron, says: "The security afforded, not only for its supporting weight, but against fire, has of late years very much increased the use of it, and may in many cases entirely supersede the use of timber." The experience of recent years, however, especially at Chicago and Boston, has materially lessened confidence in its fire-resisting character. Indeed, its power to sustain weight, when subjected to great heat, has been shown to be quite limited. It is capable of sustaining, in an intense fire, neither compressive, tensile, nor transverse strain, to any useful degree. Its untrustworthiness was shown at least two hundred years ago, for Evelyn says of the great fire of London in 1666: "The vast yron chaines of the Cittie streetes, hinges, bars, and gates of prisons, were many of them mealtd and reduced to cinders by y^e vehement heate."

To protect hollow iron columns it has been proposed to secure the passage of a current of air through them. An experiment to test this was made upon a one and one-half inch pipe, which was subjected to heat at the middle, while a strong current of air was maintained through it. It was pulled apart by hand in four minutes after the fire was applied.

All metals transmit heat rapidly, a fact which may account for the rapid loss of strength in iron when subjected to fire. If iron be used for floor beams, arch ties, or for posts, or for any purpose which exposes it to strain of any kind, it should be protected by an incasement in some slow-conducting material, such, for example, as brick, terra-cotta, or gypsum, although this latter material is active in rusting iron, and therefore should not be allowed to come in contact with it. Where gypsum is to be used a good coat of lime whitening previously applied to the iron will protect it from the action of the plaster. Mr. Hornblower, architect, of Liverpool, has patented a system of protection to iron beams by means of earthenware jackets and concrete, and Mr. P. B. Wight, of Chicago, Fellow of the Institute, has patented a system of protection to iron columns by an inclosure of plaster. These and other systems of protection are just as many concessions to the now well-established fact, the non-fire resisting character of iron.

Of the four principal materials used in construction, wood is generally supposed to be that which has the least power to resist fire. This idea, in general, is correct, and yet under certain circumstances wood will resist fire longer than iron.

When a building is on fire, known to have supports of iron, firemen are reluctant to enter, while they hesitate not to enter a burning building having wooden supports, at least until some time after the commencement of the fire.

This apprehension of danger from iron supports, the growth of experience, plainly proves the superiority of wood over iron as to a fire-resisting quality.

The late fire at Washington burned a part of the roof off the Patent Office. It was arrested in its downward course by what was supposed to be a fire-proof floor of rolled iron beams and brick arches, but which subsequently was found to be of wood.

A floor of wooden beams, placed apart in the usual way, has but little fire-resisting quality. The fire, aided by a free current of air between the beams, rapidly consumes them, as so many pieces of well-placed kindlings.

This defect in the construction of wooden floors has led to various devices, one of which is the use of plaster or gypsum, which is thickly spread upon the lathing at the bottom of the opening between the beams, and also extended up on each side. This forms a good filling, effectual in preventing the draught of air, but it has been found to induce rapid decay of the timber, and is therefore a failure.

In the use of ordinary deafening, concrete, plaster, or any similar filling, it is requisite to increase the size of the floor timbers sufficiently to sustain safely the weight of this filling. The fillings above named are a dead weight upon the floor.

If some filling be used which would sustain itself, such, for example, as wood, or if the intervening spaces be filled with so many additional floor beams, these would not only sustain themselves, but would contribute to the general strength of the floor, or the floor not needing additional strength, the beams could all be reduced in depth to the required limit of strength. An arrangement of this kind produces what is termed a solid timber floor, upon which, there being no interstices for the passage of air, the fire, retarded, acts only in slowly charring the under surface. Such a floor would resist the action of fire for many hours, and would be effectual in preventing the spread of fire.

But wood is subject to decay, and for this reason is inferior to iron, which is deteriorated by rust, generally in a very small degree. Where iron can be protected from injury by fire, it is far superior to wood. For general building purposes, however, wood, if protected from decay, is superior to iron. Our want now is some effectual, ready method of preventing decay in wood. Until something better is offered, floor beams and posts may be subjected to the kyanizing or burnetizing process, which are claimed to be effectual. It

has been proposed, after wood is kyanized, to coat it with silicate of soda as a protection from fire. Experiments on a large scale in this direction are desirable, and might well be undertaken by the general government at Washington.

Investigations lately made show that the archives of the War Department are exposed to destruction by fire, being lodged in buildings of a frail nature.

Self-protection may possibly inspire the authorities to make the indicated tests of wood, from which results may flow of great importance to the country at large.

In planning buildings to endure, it is required that the walls and partitions be made of ample thickness, of well-burnt brick, put together with the best of mortar, and that the floors, as far as practicable, be also made of brick, vaulted. Where this is not practicable, owing to the lateral thrust of the vaulting, then the floors should be of prepared timber, laid together solid, and coated with an inch of plastering beneath a wooden lath coated with the silicate of soda, the plastering largely composed of plaster or gypsum. The floor timbers should be attached to each other by spikes or dowels, and lodged at the ends on brick ledges, corbeled out from a good depth below, and secured to the walls with iron anchors. The ends of the beams should be cut inclining, so that while of full length at lower edge they may be an inch distant from each wall at the top edge, and this space between the wall and the beam should be kept open for ventilation. The floors at or below the level of the street should always be vaulted with brick; for here it will not be difficult to secure sufficient buttressing to the arches, and here where the furnaces for heating are located there is the more need of protection. All flues for heating should be of ample size and lined with earthenware pipe. Stairways, usually of wood, afford means for the rapid spread of fire from the lower to the upper stories. Where practicable, these should be of brick and stone; and the stairways of each story should be provided with doors by which to isolate it from the other stairways. All partitions should be of brick, especially those about a stairway or an elevator. All shafts for elevators, or for light or air, should be provided with doors at each floor, in order to cut off, when required, all opportunity for a current of air. Wooden furring on walls is highly dangerous; when used it should be provided with bars of filling at proper intervals to prevent draught, and incidentally the circulation of vermin.

Partition walls of brick should, when possible, take the place of lines of posts and girders, that the apartments may be reduced in size; and the openings in the walls should be provided with doors and shutters by which to isolate the apartments.

If buildings were constructed in this manner a fire would seldom extend beyond the apartment in which it originated.

To protect the interior, all wooden cornices, dormer windows, and the like should be avoided. Roofs should be of slate or metal laid upon a good bed of cement concrete. The walls should be extended well above the roof and coped with stone or iron. The exterior walls should all be of good solid brickwork. If, however, there be iron posts, as those of a store front, these should be filled in solid with brick work of ample size to carry alone the weight of the upper walls.

Buildings of the character indicated could be erected at a cost not to exceed fifty per cent. additional to that of the average city building, and in a city of such buildings damage by fire would be reduced to a minimum.

ELECTRICITY AS A MOTIVE POWER.

BY PROF. W. E. AYRTON.

THE annual discourse to working men, which is one of the most pleasing features of the meeting of the British Association, was lately delivered by Prof. W. E. Ayrton, in the Albert Hall, Sheffield, more than 3,000 workmen being present. The lecture was illustrated by a large number of experiments, while diagrams were freely used to explain points otherwise to be understood only with difficulty. Several machines were connected by wires with Messrs. Walker and Hall's works, and the capabilities of electricity as a motive power were fully demonstrated—not the least interesting experiment being the appearance of a "Sheffield grinder" polishing a knife on an electrically driven emery wheel. After some preliminary remarks upon the cost of coal and the utility of water power, Prof. Ayrton said:

In our poverty and depression, our old servant, coal, is beginning to desert us, and to demand a higher price than we can give. Water, a yet older handmaid, refuses to work at all in our houses, except for extravagant payment. Where is it that we must turn for help? Where can we find the carrier that will, at a small cost, transport our motive power over long distances? It is to electricity we must look for an answer to this question. It is to that fleet, subtle messenger to whom we trust the carrying of news, that we must trust the carrying of our motive power.

Now these machines that are employed for this purpose depend on two important discoveries. The first, supposed to have been made by Romanosi, in 1802, who found that an electric current could produce mechanical motion; the second discovery, made by Faraday, in 1831, who, after the most patient investigation, was at length able to prove conclusively the result that he had long felt in his own mind must certainly be true, viz., that a magnet must somehow be able to produce an electric current. The first of these discoveries may be illustrated by the following simple experiment. Here we have a vertical copper wire, through which we can send an electric current either upwards or downwards. Behind the wire there is a magnet, suspended on a horizontal axis, so that it can turn in a vertical plane. The magnet is so arranged that usually it stands upright, but if I send a current upwards, you observe the marked end turns to your left, while if I reverse the direction of the current, the marked ends turn to your right, the magnet in both cases placing itself at right angles to the wire. Now, why does the magnet move when the current flows along the wire? Because the wire with the current in it produces in the space surrounding it the same effect that would be caused by the presence of a large magnet. For if I hold this other magnet in this position, perpendicular to the suspended magnet, you see the latter one turns with its marked end toward your left hand, as it did when the current ascended; and when I reverse the position of the big magnet, the smaller one puts itself in the same position as it did when the current descended. From this you would anticipate that since an electric current can act like a permanent steel magnet, in deflecting a suspended magnet, and since a steel magnet can make this piece of soft wire into a magnet by being put near it, an electric current will also make a piece of iron into a magnet, a result first proved experimentally by Arago. When the electric current passes through this coil of wire, wound round this iron bar, the bar acquires the power to hold up masses of nails, but the moment the

current ceases, the iron, as you see, loses almost, but not quite instantaneously, all its magnetic properties, and the nails fall to the ground. But since, by electricity, I am able to produce sufficient pulling force to hold up bits of iron, or, at will, cause this force to cease to act, then I must be able to do just as Newcomen did, when he made his so-called atmospheric engine.

For if we cause the attraction of this electro-magnet to pull a piece of iron, or armature as it is called, against the tension of a spring, and if, just when the iron is almost touching the electro-magnet, we interrupt the current, the spring will be able to pull the iron back again, and thus by repeating the action over and over again you see we can get an oscillating motion similar to that obtained in a single acting engine. And any oscillating motion, you know, can be turned into a rotatory motion by means of a crank and a fly-wheel to make the crank pass the dead points. Now, the first man to make an oscillating electro-motor of this kind was a learned monk of Padua, Salvator del Negro, in the year 1831. But an oscillating motion has many disadvantages, of which perhaps the most important in an electric engine is that the moving armature at the end of its stroke will be at a distance from the electro-magnet. Now the electro-magnetic attraction diminishes very rapidly as the distance increases, so that when the armature begins to approach the electro-magnet there will be very little force pulling it.

The Russian philosopher Jacobi explained this in 1834, and devised a rotatory engine in which the moving parts were not merely pieces of iron but electro-magnets like the fixed ones. When the pole of one electro-magnet was approaching that of another due to the rotation of the apparatus, the currents were so arranged that there was attraction, but the moment the moving pole passed the fixed pole the electric current flowing round the former was reversed, so that there was attraction. An instrument such as Jacobi used may be seen working on the table, and like Jacobi's was originally intended to propel a boat. Here again I have a complete model boat driven by an electro magnetic engine, with galvanic battery in the boat. A third electro-motor is working a Howe's sewing machine, while a fourth is a small engine running round on a pair of metal rails. This last would no doubt pass with the world as a mere toy, but the practical philosopher sees foreshadowed in it his dream of the future, just as Stephenson, in his "Puffing Billy," no doubt foresaw the express locomotive engine of the present day.

But after some time Jacobi abandoned his electro-motor, as the fuel cost far too much. Why then trouble you with considerations regarding electro-motors? Because we have since learnt why the old form was such an expensive producer of power, and what is the proper duty in which electro-motors should be employed.

Now, it was this very question—Can an electric engine be made to work more economically than a steam engine?—that first attracted Joule, of Manchester, in 1843, to commence that all-important investigation, which lasted for six years—the determination of the mechanical equivalent of heat.

Formerly, electric currents were almost entirely produced by galvanic batteries, such as I have in my hand, in which zinc is burnt, just as in the furnace of a steam engine coke is burnt. The amount of heat that could be got from burning a pound of zinc could be ascertained in the same way as the amount of heat produced by the burning of a pound of coal, but the fact that the latter was about seven times the former was of little value in the science of electro-motors, until Joule had proved that a certain quantity of heat is always equivalent to exactly the same quantity of work, no matter how the heat be produced.

Now, experience shows that these energies are convertible into heat, and that a certain quantity of each kind of energy is mechanically *exactly* equivalent to a certain quantity of any other. If a body, or if a system of bodies, possesses different kinds of energy, then as long as no energy leaves the system, or enters it from without, this sum is *perfectly constant*, no matter how one of these forms of energy may change into another form. Energy is in fact as indestructible as matter, and this law has one of its proofs in the long unsuccessful search for a perpetual motion. Since, therefore, a pound of ordinary coal burning gives out seven times as much heat as the burning of a pound of zinc, we may say at once that a steam engine would give seven times as much work as an electric engine for equal weights consumed, if in both cases all the heat could be turned into work; or, since zinc is about twenty-four times as dear as coal, that a steam engine would be about 150 times as economical as an electro-motor, worked by a battery.

But so far we have only considered the law of "conservation of energy." There is, however, another, and no less important principle, called the "dissipation of energy;" and this law tells us that although the energy of a system cannot by itself increase or diminish, yet our power to convert one form of energy into another is continually growing less, our stock of available energy is gradually falling. Our mountain lakes, our vast store of coal, is practically useless until either the water is set in motion, rolling down the hill-side, or until the particles of the coal are set in rapid vibration as its slowly burns; energy of position, energy of chemical affinity, are of no use to the manufacturer until turned into kinetic energy or energy of motion. But from friction of various kinds, whenever energy exists in the kinetic form, some portion of it is being continually converted into heat. Whenever man or nature utilizes energy it must be first turned into some kinetic form, and whatever be the aim of the special machinery employed, some of this energy passes into heat. We cannot make even a clock go without regular winding up, although the only useful work done by the clock is to turn its hands at regular speeds; the earth's energy of rotation is now, like the moon's in past ages, gradually growing less, and is being converted into heat on account of tidal retardation; the earth, moon, and sun, and all the planets are losing their energies of motion, and relative positions, to be all ultimately turned into heat.

But, at any rate, it will be said there will still remain the heat, and since heat can be converted back into other forms of energy, we shall be none the worse off. But it must not be forgotten that whenever heat is produced some passes off by conduction through even our best non-conducting substances, and by radiation into space from even our best non-radiating surfaces; and this conducted and radiated heat, although it may impart some trifling warmth to unseen worlds, is, for the greater part, entirely lost to our universe. And even were it not so, even had we perfectly non-conducting coatings, and perfectly non-radiating surfaces—had we, in fact, the most perfect heat engine that our study of the science of heat would lead us to believe theoretically possible, one with no friction, no loss of heat by