

order to have a very hot and very fluid mass, to allow the metal to fall into the crucible, and then the consumption of coke varies from thirty to forty per cent. It is possible to smelt 100 kilogrammes of steel pig in thirty minutes.

Mr. Piat's portable oscillating furnace and crucible cupola are destined to render genuine services in smelting works. More than two hundred of these apparatus have been in operation since the exposition of 1889, in France, Germany, Italy, and England. The use of them has begun to extend in a general manner in the smelting industry, and it is probable that it will greatly increase when smelters have found out the serious advantages that these apparatus present, from all points of view.—*Le Génie Civil*.

PROGRESS OF THE STARCH INDUSTRY.

ACCORDING to the last statement from the Bureau of Statistics, about 14,000,000 pounds of starch were exported during eleven months of last year, against half of that quantity for the year previous. We are informed by good authority that the export movement was somewhat larger, and that most of the starch sent abroad is disguised as flour to prevent competitors from tracing the shipments, hence the Bureau of Statistics is not to blame for inaccurate figures. The movement of corn and potato starch to the four ports of the United Kingdom has been unusually large for the past few months on account of the short crops of corn and potatoes on the other side. It is very unusual to send potato starch out of the country, and previously the article was imported to the extent of 509 tons per year, but during the past eight months no foreign starch has arrived. This product of the potato is yet of comparatively small importance, as its use is confined to the mill trade. The total production is estimated at 11,000 tons per annum, which is 500 tons more than the consumptive outlet. The article is made by various small concerns throughout the country. Indications point to a scarcity and higher prices on account of the large quantity used for making dextrine since last autumn. The latter is a new American product, made necessary by the small crop of potatoes in Europe, and the consequent light supply of foreign dextrine, which formerly had no competition in this market. In case of better crops next summer and thereafter, the importation of dextrine will no doubt be resumed as usual, as it is claimed that the new duty of 1½ cents per pound will not prevent its sale on the American market.

Corn starch is the leader, with an annual production of about 350,000,000 pounds. The number of factories in operation has been reduced from twenty-five to thirteen because of over-production. Some of the larger mills are working from 1,000 to 8,500 bushels of corn per day, as only twenty-five pounds of starch can be obtained from a bushel of corn. Manufacturers are complaining of the very narrow profit in the business, and were it not for the odds and ends which are transformed into gums for special uses, it is said there would be absolutely no money in the corn starch trade, except for those firms manufacturing on a very economical basis. The violent fluctuations in the corn market are always a disturbing element, as it is not an easy matter to determine when to lay in supplies. A favorable purchase of raw material leaves the manufacturer of starch in a position to meet competition, but a high market for corn may rob him of his profit for a while at least, as an advance in the price of raw material must be permanent to have any influence on starch.

The rivalry between the combined forces and the independent faction continues, but the competition for trade is devoid of the unpleasant friction experienced when the combination was formed.

Wheat starch is another article that is over-produced, although there are only seven mills devoted to its manufacture. The consumption does not exceed 10,000,000 pounds per annum, but efforts are being made to push its sale as a substitute for corn starch in the laundry and among industrial establishments of the East.—*New York Price Current*.

THE USES AND APPLICATIONS OF ALUMINUM.*

By G. L. ADDENBROOKE.

THE utility of a metal in the arts is governed by its physical properties and the price at which it can be produced in an available form. I propose, therefore, as a commencement, to deal with both of these aspects of the question this evening, in order that a fairly correct basis may be arrived at on which to estimate the uses to which aluminum is applicable; and, in what I say, it must be understood that I refer generally to aluminum itself, or to aluminum alloyed with a few per cent. of other metals, unless it is mentioned to the contrary, and not to aluminum bronzes, or bronzes consisting chiefly of copper alloyed with a few per cent. of aluminum.

Let us commence with the cost of the metal, as that so largely determines its sphere of usefulness. Just three years ago, in this room, Mr. William Anderson described the Deville-Castner process, which had then just been put in operation by the Aluminum Company of Oldbury, near Birmingham. It was then stated that it was proposed to manufacture aluminum at 20s. per lb., or at about one-third of what its price had been previously, and still leave a satisfactory commercial profit. These anticipations would have been duly realized but for the contemporaneous perfection of the electrolytic methods of reducing aluminum, which being brought into use on a large scale, have resulted in an enormous reduction in the cost of production, and this has constantly reduced the market price of aluminum in a manner which is probably without parallel in the industrial history of metals. Starting three years ago, as has been mentioned, at 20s. per lb., the price of aluminum quickly fell to 15s., then to 13s., next to 8s., and even 6s. It was thought about a year ago that the climax, for the time being at any rate, had been reached when the Pittsburgh Reduction Company, of Pittsburgh, Pa., announced that they were prepared to supply aluminum at a dollar, or 4s. 2d. per lb. But the competition chiefly of the Aluminum Industry Company

of Neuhausen, Switzerland, whose works are operated by water power and are on a large scale, has led to still further reductions, and at present, in considerable quantities, aluminum of 99 per cent. guaranteed purity is obtainable at 2s. or even less per lb.

On anything like the present output this price is hardly a remunerative one for the companies engaged in production; and it seems to me that it is improbable that there will be much greater reduction at present. On the other hand, I do not think the price is likely to rise very much again, because a larger consumption of the metal would make this rate a paying one, which would lead to increased output. This, then, is the cost basis on which we have to estimate the openings for aluminum during the next year or two, a cost, bulk for bulk, not greatly exceeding that of copper, for at present the cost of copper is about 5d. per lb., and, since it is 3½ times as heavy as aluminum, the latter, at 2s. per lb., would equal copper at

$$\frac{24 \times 2}{7} = \text{say } 7\text{d. per lb., or a relative cost for equal quantities of 5 for copper to 7 for aluminum.}$$

It may be interesting to outline briefly the processes by which these astonishing results have been obtained, particularly as finality has by no means yet been reached; and should the uses of aluminum warrant a largely increased output in the future, considerably better economical results could be attained.

As usual, success has been achieved by the labors of many minds, but there are two patented processes under which most of the aluminum at present made is being manufactured. The first is that of Mr. Hall, of Pittsburgh, Pa., whose patents are owned in America by the Metal Reduction Company, of Pittsburgh, and in England by the Metal Reduction Syndicate, of Patricroft, near Manchester. The second is that of M. Heroult, a young French engineer. This latter process is controlled by the Societe Electro-Metallurgique, of Troyes (Isère), in France, and by the Aluminum Industry Company, of Neuhausen, Switzerland, at which latter works the largest plant in the world for the reduction of aluminum and its subsequent working is situated.

Although, however, two in name, there is, in fact, very little difference between these two processes, so far as the details have been made known, and therefore, for my purpose this evening, one description will answer for both.

In both cases the oxide of aluminum, or alumina, Al_2O_3 , is the material from which the metal is reduced. This is dissolved in a fused flux, consisting of fluorides of aluminum and sodium, which simply serves as a vehicle to carry the alumina. The furnace for effecting the operation is made in the form of an iron-cased box, which is thickly lined with carbon, having a cavity in the center into which the materials for reduction are introduced. Two or more of these furnaces are placed in series, and one pole of the dynamo is connected to the carbon lining of the first, forming the cathode. A large block of carbon carried on an adjustable support, and arranged so that it can be dipped into the central cavity of the furnace, forms the anode. From it connection is made to the lining of the second furnace, and from the carbon anode of the second furnace, if there are two, the main passes back to the other terminal of the dynamo.

In starting the plant, the carbons are brought well down in the furnaces, and the current turned on. At first considerable resistance is offered, but as the materials in the furnaces get warm this decreases, and the carbon anode can be raised somewhat. Decomposition takes place at about a full red heat, the alumina is resolved into its elements, the oxygen partly unites with the carbon, and is given off as carbonic oxide, and partly escapes free, while the aluminum sinks to the bottom, and gradually accumulates. When a sufficient quantity has collected, it is tapped off and run into moulds without interrupting the process of reduction, which is thus continuous. As the aluminum in the furnace is decomposed, the resistance rises, as the workman can see by watching the ammeter, and this is an indication to him to add more alumina.

It will thus be seen that the process is a pretty simple one. First, we have the dynamos, which must be driven by steam or water power, and which, as they are operated continuously, can be worked to the best advantage. The load is fairly even, and therefore the wear and tear on this part of the plant should be small.

Then we have the furnaces, which are not expensive, and will only require the carbon lining and anodes renewed occasionally.

Lastly, the flux, acting simply as a carrying vehicle, needs only small additions from time to time. The four great items in the cost of production of aluminum are, therefore, the cost of the electric energy, of the alumina required, wages and superintendence, and depreciation and interest on capital employed.

Now, in the Hall process, it is found that 22 electric horse power flowing through the bath, at a potential of 8 to 10 volts, for one hour, is what is required to reduce 1 lb. of aluminum, and this can easily be produced by the combustion of half a hundredweight of coal, which at 10s. per ton means a cost of 3d.

As to the alumina, I am informed by the Metal Reduction Syndicate that the anhydrous alumina which they use, and find most suitable, on account of its freedom from impurities, costs £30 per ton, and yields about 50 per cent. of its weight in aluminum. The cost, therefore, of the raw material is at present about 6d. per lb. for the aluminum contained.

The cost of the pound of aluminum then totals up to 2s. 9d. per lb. for the aluminum extracted, unless indeed water power is employed, as at Neuhausen, where the first item is of course considerably reduced.

Coming now to the capital required, a horse power of plant, working for 24 hours, produces in practice about 1 lb. of aluminum. Supposing the plant works 300 days a year, we have 300 lb. of aluminum as the product of an indicated horse power of plant working for a year. Now, such a plant as this could easily be erected complete, including buildings and all accessories, for £30 per indicated horse power available; and supposing we take upkeep at 10 per cent., and interest and profit at 10 per cent., this represents £6 per annum to be spread over 300 lb. of aluminum, or 5d. per lb., which is a very liberal estimate, and may well include the cost of carbons and fluxes. For these three items

then we have a total of 1s. 2d. per lb. Finally come labor, superintendence, and administration expenses. These so much depend on the output, which at present is small, that I shall not attempt to estimate them. It will be sufficient for my purpose if I have shown that the present price of aluminum ingots, say 2s. per lb., cannot leave much margin of profit on the present rates of output, which are about as follows: The Aluminum Industry Company, 1,000 lb. per diem; the Pittsburgh Reduction Company, 600 lb. per diem; the Metal Reduction Syndicate, of Manchester, 300 lb. per diem; Cowles Company, 600 to 750 lb. in alloys. At the same time it is sufficiently near the remunerative level to prevent any great advance, except by a reduction of output, or some agreement among manufacturers.

To get further cheapness, a larger demand and production are needed, which must come within a moderate time, when we may safely calculate on aluminum comparing at any rate on equal terms with copper as to price for equal bulks; but from what I have shown I think it is pretty clear that we cannot look for much reduction on the price I have named in the immediate future. Improvements will certainly take place in the processes of manufacture, and I feel very hopeful of them, but they will probably be in details rather than in any fundamental alteration of the present electrolytic process of reduction, and will chiefly take the form of improvements in the methods of obtaining pure alumina or some other salt of aluminum, and in the method of operating the furnaces, in which at present only about 25 per cent. of the energy is utilized for reduction directly, the rest being absorbed in heating the materials. Electric heating has so far been, I believe, found preferable to direct heating, but I cannot help thinking that, at any rate where steam engines are employed, further experience will lead to improved forms of apparatus being devised, which will admit of the heat required being applied directly and more economically than through the intermediation of a steam engine, which, as a heat producer, is so very inefficient.

To pursue these lines of thought further would be speculative, whereas my object this evening is of a more practical nature; therefore, having settled on an approximate price at which aluminum will be obtainable for present use, it remains to be seen what field this price, coupled with this peculiar physical and mechanical properties, will enable it to occupy.

Within the last ten years the quality of metal manufactured has been very much improved, and the larger quantities in which it has been dealt with have given better opportunities of estimating accurately its nature than was possible before. Most of the metal made is now of over 99 per cent. purity, and the reduction in the amounts of iron and silicon contained in it, which are the chief impurities, has altered and improved its working qualities considerably, when it has to be rolled, spun, and drawn.

To show exactly what its properties are, I have here a cast bar of pure metal, about ½ in. wide, ¾ in. thick and 1 ft. long. Taking the ends of that in my hands, you will see that I can bend it double, bringing it into the form of a rather elongated O, without breaking; that is about the limit of what it will stand. As regards hardness it is rather softer than copper, and in the lathe, or under the file, behaves in much the same way, having a strong tendency to pull, and tear, and clog the tools. Like copper, too, it is softened by being plunged hot in cold water, and hardened by being cooled slowly.

Clearly, in this state, it is not very suitable for castings, and, just as zinc and tin are added to copper to improve its qualities, so some similar additions must be made to aluminum, if it is to be as useful in this form as its other qualities lead us to anticipate.

In the endeavor to improve the qualities of aluminum, without detracting appreciably from its characteristic properties of lightness and incorrodibility, I have gone over some old ground, and perhaps entered a little new, and a few notes on the results of additions of other metals to aluminum may be interesting, as the literature on this subject is rather fragmentary and incomplete, and early experiments were mostly performed with impure metal.

To begin with, the pure metal does not cast quite so well, nor is it as hard or strong as when it contains 2 to 3 per cent. of silicon, though its malleability is decreased, and it has a scratchy, sandy feel.

The addition of iron appears to be simply detrimental, leading to porous castings, while the metal is of a rotten nature.

Copper gives much better results; it hardens the metal considerably, when added up to 5 or 6 per cent. After this brittleness is produced.

My experience with copper, however, is that the alloy does not stand remelting well, but soon becomes porous; on the other hand, until it has been several times melted, and allowed to stand, scum is apt to form, and mingle with the metal, producing bad marks in the casting. The metal also still pulls in the lathe. Silver alloys with aluminum very well, but its cost puts it out of court for most purposes.

Zinc hardens aluminum, and also toughens it when added to the extent of 3 or 4 per cent., but the resulting metal is difficult to turn, and the alloy is not a very clean one; it does not stand remelting well.

The addition of tin appears primarily to have two actions—up to three or four per cent. it makes the aluminum short, but improves its turning qualities; if 10 per cent. is added, the bar is at first as pliable as the pure metal, and of about the same strength, but if this metal is once or twice remelted it soon becomes crystalline.

Nickel has much the same effect; when added to copper, it however produces a closer grain, though still leaving a bad surface under the tool.

Though the qualities of aluminum therefore are improved in some respects by the addition of alloys, none of them seems to produce alone quite what is wanted. In combination, however, better results are obtainable, and I have here some specimens made by the Phoenix Engineering Company. The exact composition of these I am not at liberty to disclose at present, but it will be seen that the metal is both whiter and much harder than aluminum, while it can be turned with practically the same facility as brass, leaving as good a surface. A good example of the alloy will have a rigidity slightly superior to ordinary cast brass, though it cannot be bent to the same extent; however, it is still fairly malleable, and bears considerable extension under the

* Read recently before the Society of Arts, London. From the *Journal*.

hammer. As with so many other alloys, the best results are obtained after the metal has gone through a certain amount of mixing and remelting; afterward frequent remelting renders it more brittle, and is apt to produce porosity. This, in fact, constitutes the chief difficulty in casting aluminum and it is aggravated by the fact that most of the objects hitherto made in aluminum are small, while, owing to the lightness of the metal, higher heads are needed than for brass or iron; there is therefore necessarily a good deal of remelting if metal is not to be put aside. This difficulty is, however, one which practice and the use of aluminum for an increasing number of objects will diminish.

To illustrate what can be done with this alloy, I have here a dumpy level made from it, including all the screws and working parts. Further, I have camera screws and nuts, tripod heads, and a portable galvanometer, while Mr. Dallmeyer has been kind enough to send down examples of his lenses, particularly his new ones, all the parts of which, except the tubes, have been made of this alloy. It will be noticed that satisfactory screws can be cut in the metal. I have here also a specimen of a small resistance box, of which the top is made of it, and which appears to answer very well.

The alloy will also be useful, I think, for the frames of light motors, and for some of the working parts, for parts of portable microscopes and telescopes, range finders, heliographs, projectors, arc lamps, field telegraph apparatus, stands for portable lamps, and for a considerable number of other purposes where a fair degree of strength and rigidity is needed, combined with lightness and incorrodibility.

Before passing on from the consideration of alloys, I must mention the beautiful one of aluminum and gold, containing, I believe, about 23 per cent. of the former metal, which has been discovered by Professor Roberts-Austen, and which he has been kind enough to bring to-night. In structure it is crystalline, but the interesting point about it is its beautiful rose pink color, which is quite different from anything that has been observed in metal before.

Of alloys with aluminum in general, it may be said that they decrease its malleability, and that, for metal which has to be rolled or drawn, it is usually expedient to employ the pure metal, in fact the purer the better. I think, however, that as the handling of the metal is better known, some of these alloys may prove useful, and provide us with harder sheets and wires of higher breaking strain than can be obtained from aluminum itself.

Passing now from cast aluminum to rolled and drawn. There are on the table some 5 lb. ingots cast in iron moulds, such as are used for rolling from. These can be rolled right down into sheets of any thickness cold and without annealing, of which there are several specimens before you, ranging from the ordinary grades down to one which I have, and which is only $\frac{1}{16}$ of an inch thick; while, to proceed further, foil can be beaten out into leaves, the thickness of which is about $\frac{1}{1000}$ of an inch. This leaf has almost entirely superseded silver for gilding on account of its permanences, as a good instance of which I can show you a book of leaf which was made in 1868, and has been in London since. You will perceive that it is as bright as the day it was made.

Sheets of aluminum cold rolled become very hard and quite springy; in fact, their rigidity is greater than that of ordinary brass sheets. They will stand a fair amount of bending, and can quickly be made quite soft by annealing at a temperature of about 400°. It is evident that such sheets are applicable to a number of purposes in the flat. For instance, they have been used for making canoes and the hulls of steam launches, or for parts of photographic cameras. Sheaths for holding photograph films and a number of the parts of portable instruments are also readily made from aluminum sheet, and it will also, I think, have a future for ornamental work for electroliers and gas brackets, especially in conjunction with iron work, with which it forms an excellent contrast; but its greatest value lies in forming the substratum, so to speak, for stamping and spinning.

Of the various useful articles which will be made of aluminum in the immediate future, it is safe to say that a large proportion will be stamped or spun, for aluminum lends itself particularly well to this work, and anything that can be so made in other metals can be carried out in aluminum. It has, like other metals, a few peculiarities of its own which require to be mastered, but when this is done, we have a metal which is as tractable in the hands of the workman as silver. As instances, there are on the table some fine stampings of a couchant lion and examples of buttons, also forks, the backs of brushes, etc., which show how much can be accomplished, and what a nice effect the work has.

Of spinnings, Messrs. Still & Co. have been kind enough to send some fine examples: there is, for instance, a stethoscope entirely spun up, including the tube and both ends, from a circular plate, such as I have here; a more perfect specimen of what can be done with a metal, and what it will stand, it would, I think, be difficult to conceive—though so light, it is yet very rigid. There are also examples of surgical specula; an ewer and basin; and, lastly, some helmets for firemen or military purposes; these, Messrs. Still & Co. assure me, they consider as strong and stiff as ordinary brass, of which there is also an example, that its weight may be compared with those of aluminum.

Then I have here an example of the aluminum flask, of which so much has been said lately in connection with the German army; it will be observed how light and strong it is. For comparison there is another somewhat similar one of English manufacture. The uses of aluminum for cooking utensils, probably for cartridge cases, should also be noted here.

Lastly, there are some very interesting plaques and picture frames, the work of the Scovill Company, of New York, which are an interesting example of scratch brush work.

Turning now to a slightly different field, here are examples of tubes. Some provided by the Mannesmann Company, as examples of their power, are 12 or 14 ft. long, and of excellent quality. For the remainder I am indebted to the Phoenix Engineering Company. All these tubes, I need hardly say, are solid drawn; and it will be noted what excellent examples of workmanship they are. For telescopes, and wherever light-

ness is essential, they must supersede brass or German silver. Whether they will answer for bicycles still remains a moot point. I have tested two sets of tubes of the same dimensions—one of steel and the other of aluminum—in the following way. The tubes were supported in V grooves a foot apart, and a lever was brought down on the center of the tubes between the supports, a pad and narrow ring being used to secure a fairly even pressure. The lever was then adjusted, and it was found that the aluminum tubes stood about half the strain of the steel tubes, though their collapse was a little more complete on passing the critical point. As an instance, an aluminum tube one inch in diameter and 40 mills thick stood a strain of 200 lb. applied in this way. This, I think, must be considered very satisfactory.

Of the applicability of aluminum to opera and field glasses it is needless to speak, but there is an example on the table of a glass made in 1864, which has been in constant use since. In 1870 the wheel of a carriage passed over it, but it was afterward straightened out and made usable. It has made two voyages across the Atlantic, two across the Pacific, and has had other shorter experiences of the sea air, besides lying on one occasion for some time in salt water. This disposes of the idea that aluminum is readily spoiled by contact with sea air. For my part, I have kept strips of aluminum for two or three weeks in salt water, and have noted very little effect.

I might continue this somewhat discursive paper further, and it is obvious that I have only enumerated a few of the uses to which aluminum can be put, but I have rather relied on showing from the examples before you that aluminum is an easily workable metal, and can be worked into almost any form which metals, such as copper, brass, and silver, are capable of assuming, having once grasped which, each in his own sphere can find uses to which it adapts itself. At its present price, it can be classed as eminently a useful metal, and the lower the price becomes, the wider will be its sphere of utility.

There is, further, one goal toward which aluminum workers will look forward, and the attainment of which it is not unreasonable to expect in the future. At present the price of aluminum is about four times that of pure copper for equal weights, and its output is little more than a ton a day for the whole world. In the improvements in the process of reduction, and an output of some thousands of tons per annum, is it looking too far ahead to anticipate that the price will be reduced to that of copper, when aluminum, with its conductivity of 200 per cent. that of copper—weight for weight—would, in a large measure, replace the latter metal for mains for electric lighting?

In what I have said nothing has been mentioned about solder. I have here an example of some joints I have had made, which are fairly satisfactory. Strength of joint is secured, but the process of making it requires a good deal of care, on account of the high melting point of the solder and the difficulty of getting it to flow readily. Still, it can be done. Messrs. Balfour & Co. have, however, informed me that they have a solder which they propose to bring out shortly which is a great improvement on previous ones. They have brought some examples of work done with it to-night, from which it will be seen that the joints are quite invisible. I have not yet seen any actual joints in the process of being made, but aluminum workers will await further results with interest.

DISCUSSION.

The chairman said Mr. Addenbrooke had referred to the probability that where steam engines were employed further experience would lead to improved forms of apparatus, which would admit of heat being applied directly; but it seemed to him that that was very doubtful if the heat were applied to the carbon, which was the reducing agent, because it required more heat to dissociate aluminum than it did to dissociate the products of the reduction, which he held in this case was carbon anhydride. He held the effect was due to the combined effect of heat and the dissociating influence of the tearing electric current. But of course this was a matter for discussion. Mr. Addenbrooke had referred to the interesting alloys of aluminum with other metals, and mentioned some facts which were perfectly new to him, especially that nickel and aluminum appeared to disintegrate spontaneously. There were other cases in which alloys behaved in that peculiar way, but they were very rare. He also referred to the alloys of aluminum with the precious metals, and on one of the series he had carefully worked recently, and found that alloys of aluminum and gold possessed certain peculiarities which deserved very careful attention. The melting point of gold was 1045° C.; when alloyed with 10 per cent. of aluminum, the melting point fell about 400°, and the alloy was as white as silver; but on adding another 10 per cent., the melting point rose to 20° above that of gold itself and the alloy was a brilliant purple. By adding further quantities of aluminum, the melting point was again reduced until it came to that of aluminum itself, about 650° C. He believed that was the only case known, free from mercury, in which the melting point was higher than that of the least fusible of the constituents, and pointed to the fact that the union of the two metals must be very peculiar indeed.

Mr. S. G. Gordon said the paper was very interesting, and he regretted that he could not add any information, as he had very little opportunity of doing anything with aluminum except seeing the working of it by the Mannesmann process. In that way pure aluminum worked very satisfactorily, as was proved by the spinning, and in other ways. The Mannesmann Company had made large quantities of aluminum tubes, and found that as long as the metal was pure there was no difficulty in working it, and it would stand repeated rolling, cold, without injury. It had been mentioned that a small quantity of silicon had a great influence on the casting properties of the metal, and that was a line of research which should be followed up, the alloys which had hitherto been made having usually consisted of a fairly large proportion of other metals.

Mr. B. H. Brough said he exhibited, at one of his late Cantor lectures, a series of mine-surveying instruments, made of aluminum, to show its applicability to such purposes. Of course, lightness in this case was of the utmost importance; and any one who had to

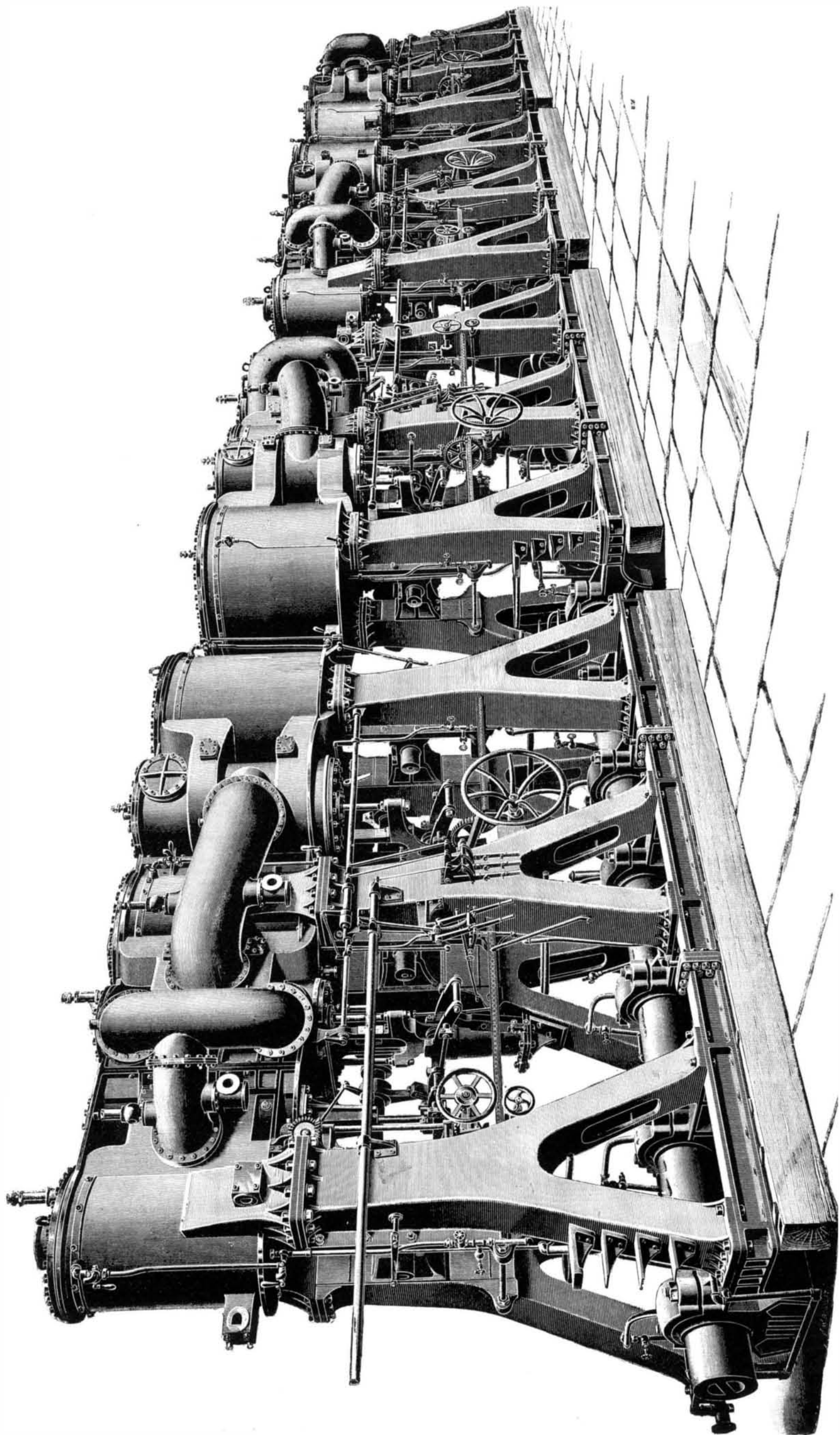
carry surveying instruments through the tortuous passages of a mine, or up the steep sides of a mountain, where every additional ounce became a grievous burden, would appreciate that; but, since then, he had had an opportunity of testing the wearing capacity of these instruments, and did not find them altogether satisfactory. He had used a theodolite as an educational instrument, with a class of about thirty students from the school of mines, and it did not stand the hard usage it was thus exposed to. The screws stripped, and the wear had been very bad, so that it might be safely asserted that aluminum was unsuited for such instruments where an occasional stress had to be borne; for whenever the metal was bent out of shape it seemed almost impossible to restore its original adjustment. He noticed in that week's number of the German mining journal a note about the Neuhausen Aluminum Works, stating that about 54 per cent. of the daily output was consumed by German steel makers, as an addition to molten steel, with a view to obviating the formation of blowholes. If that were so, it seemed a very important use, and worth mention in the paper. When the members of the Iron and Steel Institute visited the aluminum works at Pittsburg, they had presented to them, as a souvenir, a little aluminum box, which was one of the prettiest objects he had ever seen. It consisted of a very tasteful design, and showed very clearly how ornamental workmanship in this metal could be made.

Mr. C. W. Parker (Messrs. Balfour & Co.) said he was not at liberty to go into much detail on this matter, but there was no doubt that this metal was very useful and his firm had just produced a very reliable solder, the best yet tried, which would be a great service in many ways. One great point about it was that it did not oxidize, and, further, it amalgamated with the metal in the soldering. On one of the pieces he had sent, it had been hammered, and though the metal had bent, the joint had not given way. The solder was composed of aluminum and tin; was patented, and instructions for using it would be given to licensees.

Mr. Walter T. Reid said the question of soldering seemed to be of great importance. The composition of one had just been published in *Dingler's Journal*, consisting of 50 cadmium, 20 zinc, and 30 tin. Like other aluminum solders, it was said to be better than the metal itself, and to do everything required of it. He had made some experiments in soldering aluminum, and found that one of the chief points was a flux to cover the joint, as you then had a much better chance of getting a sound joint. Probably the surface of the metal became covered with a thin film of alumina, which prevented the solder flowing. He had also made a few experiments with aluminum as pure as it could be obtained, and had one or two failures to record. It did not answer his expectations, perhaps because they were too high. He found it would not stand sea water, nor even a solution of pure chloride of sodium: the metal was corroded in a very peculiar way, almost as if there were impurities in it, but on cutting out the corroded portions, and testing them, he found they were as pure as the bulk of the metal. Another thing he tried it for was cartridge cases, but, he found, when subjected to atmospheric influences, either with black powder, or with some of the niter compounds which formed the basis of smokeless powders, it was corroded, not perhaps more than brass, but quite enough to interfere with the strength of the metal. It was well known that the pressure of a very small quantity of sodium had a very deleterious effect on this metal. He should like to ask Mr. Addenbrooke if he had any information as to the action of ordinary liquids used for beverages on aluminum. Some time ago, in the German papers, there was some allusion to an alleged case of poisoning through the action of brandy on the metal of one of these flasks, and although not proved, the statement was sufficient to discourage their use.

Mr. Parker said the solder he referred to required no flux. There was a specimen on the table which had been in a salt bath for some time, and it was not at all oxidized.

Mr. Addenbrooke said he thought the chairman hardly understood his reference to the use of heat: he did not mean to reduce the metal, but simply to bring the bath to a red heat, which was now done by the current itself. In electric heating you had to put coal under the boiler, turn the water into steam, pass it through the engine, and then operate the dynamo, which was an uneconomical mode of producing heat, though of course you had the heat inside the furnace instead of outside, which might help to balance it. With regard to alloys of aluminum with small quantities of other metals, the work he had done had been with aluminum of over 99 per cent. purity, and in ordinary work he had noticed that the addition of $\frac{1}{2}$ per cent. of other metals did not make much difference; you required 1 or 2 per cent. before perceiving any effect, but no doubt by testing the breaking strain accurately, you might find there was a difference. It must be remembered that you had, say, $\frac{1}{4}$ per cent. of impurity to start with, so that it was impossible to say what was due to the added metal, and what to the impurity. Perfectly pure aluminum had not been furnished, and he did not think its electrical resistance had yet been accurately determined. It was tested some time ago, when the metal might have had from 2 to 3 per cent. of impurities, and they knew what a great difference a slight impurity made in the resistance of copper. The figure usually given was about 56 per cent., but in some samples he had measured he had found 58 per cent. of copper. The mention of the survey instrument introduced a point on which some stress ought to be laid. People talked about aluminum as if it were something quite definite, whereas, for all these instruments, an alloy of some kind ought to be used. If they were made of a suitable alloy, he would not say they would have lasted as well as brass, but they would certainly wear better than ordinary aluminum even with a little silicon in it. With regard to the addition of aluminum to steel and bronze, he did intend to refer to it, as it was exceedingly interesting, but he thought the scope of the paper was large enough without going into it. One gentleman said he found he could solder aluminum better with the use of a flux, but the usual methods were without any flux, which was generally found to be a nuisance. He had noticed some discrepancies, with regard to the action of salt, but fancied they might be traced to the fact of a rather impure



THREE-STAGE COMPOUND ENGINES OF THE NEW CRUISER NEW YORK

sheet being rolled cold. It that were the case, it disintegrated in laminae, and the salt got underneath and forced out the metal, forming a sort of exfoliated surface. With a really pure metal, well rolled, there was very little action indeed. He had put some in salt water with various organic matters and left it for weeks, and it was very little acted on. He also put some in a bottle of cider and left it uncorked for many weeks, and there was very little action. Most of the soldering must be done with a blowpipe, but an aluminum bit to work over the surface was a useful addition. The difficulty was that the solder did not flow well. You had to heat the metal up to a certain point, when it was just beginning to disintegrate, apparently before the solder began to take, first it went to a pasty state, and then, on a rise in temperature, it began to flow. He hoped the new solder spoken of would be more successful. The melting point of the solders he had used was nearly that of aluminum, and it was almost impossible to do fine work with it without many failures; you were so apt to melt the sheets. There was a method of autogenous soldering by bringing the two surfaces together, and pouring metal on to them until the edges melted and united together, and then cleaning the metal off; it could also be done by means of electricity, but he had not had much experience of these.

ENGINES OF THE UNITED STATES CRUISER NEW YORK.

We give illustrations of the engines of the United States armored cruiser New York, one of the vessels

after and each forward engine crankshaft, so that the engines may be quickly coupled or uncoupled. It is the intention to use the after engines only for moderate steaming. Each engine with its auxiliaries is located in a separate watertight compartment and will be entirely independent of the others. The main condensers are of composition. They are composed of three sections, which are bolted and riveted together. The sections are 5 ft. 9 in. in diameter and have a total length of 9 ft. between tube sheets. Each condenser contains 3,776 tubes of No. 20 B. W. G. thickness of metal. The outside diameter is $\frac{5}{8}$ in. and the cooling surface 5,560 square feet. Each tube is packed separately, so as to allow them to expand and contract independently. The total cooling surface is 22,240 square feet. Refrigerating water is supplied by separate centrifugal circulating pumping engines, there being one to each set of main engines, having a capacity of 8,000 gallons per minute. The air pumps are single acting, each with two pistons 25 in. in diameter, and 18 in. stroke. They are driven by vertical engines with cylinders 12 in. in diameter and of the same stroke as the pumps. The steam cylinders are placed directly over the pumps.

Steam is supplied by six double-ended steel boilers arranged in three groups of two abreast below the protective deck. There will be two auxiliary boilers above the protective deck. There are three chimneys. The following are the particulars of the boilers: 15 ft. 9 in. diameter and 18 ft. long. Eight furnaces of 3 ft. 3 in. in diameter to each boiler. The grate bars are 6 ft. 4 in. long. The tubes for main boilers are of steel $2\frac{1}{4}$ in. outside diameter. The tubes for the auxiliary boilers

heat and power to supply our wants, to maintain our manufactures, and to expedite our locomotion. These same rays are now in a similar way hastening the growth of trees and making wood, the difference between wood and coal as fuel being only age. They are now also furthering the annual growth of grasses, corn, fruits and vegetables to become food for beast and for man, and to supply them with fuel to maintain their life, their strength, and their capacity for work. The same rays playing on the surface of the waters promote the evaporation of the liquid into gas, which, mixing invisibly with the air, gives evidence of its presence when the lowering of temperature causes its condensation into the floating clouds and its ultimate return into the waters in the form of the gentle rain, the rippling brook, the roaring torrent, or the flowing river. The sun's rays, again, produce that variation of temperature in our atmosphere leading to currents of air which sometimes fan our faces with cool and refreshing breezes and at other times rage and roar with the relentless fury of a tornado. The sun, together with the moon, so attracts the mobile waters of the ocean that it produces great periodic waves and currents known as the tide, which ebbs and flows with such uniformity and regularity that we can calculate the rise and fall of the water at any particular spot, and its rate of flow, not only at the present day, but for any future time, provided the geographical conformation of the land and the bottom of the sea remain unaltered.

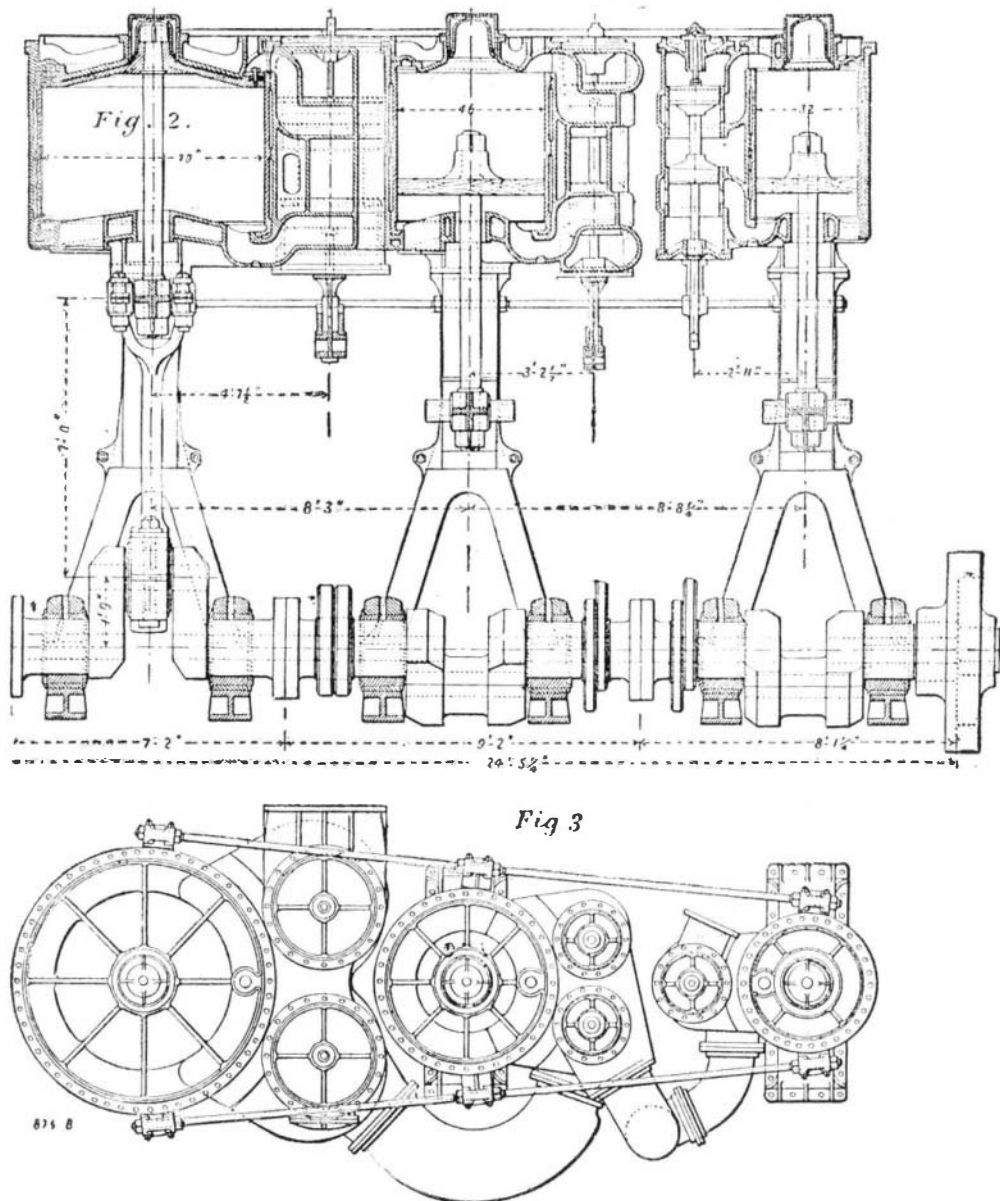
Coal and oil pent up in the bowels of the earth and water accumulated in the higher levels of the land are our great stores of energy, available for the wants and purposes of man. The wind, the running streams, and the flowing tide are the passing forms of energy which are available for our present use, while food is the particular form of fuel which maintains life and provides the means of doing work. These are all natural sources of energy; while gunpowder, gas, compressed air, steam, chemical affinity, etc., are artificial sources which the ingenuity of man has fashioned for his use.

In that interesting work of Smiles, "The Story of the Life of George Stephenson," we read: "One Sunday, when the party had just returned from church, they were standing together on the terrace near the hall, and observed in the distance a railway train flashing along, throwing behind it a long line of white steam. 'Now, Buckland,' said Mr. Stephenson, 'I have a poser for you; can you tell me what is the power that is driving that train?' 'Well,' said the other, 'I suppose it is one of your big engines.' 'But what drives the engine?' 'Oh, very likely a canny Newcastle driver.' 'What do you say to the light of the sun?' 'How can that be?' asked the doctor. 'It is nothing else,' said the engineer; 'it is light bottled up in the earth for tens of thousands of years—light, absorbed by plants and vegetables, being necessary for the condensation of carbon during the process of their growth, if it be not carbon in another form; and now, after being buried in the earth for long ages in fields of coal, that latent light is again brought forth and liberated, made to work, as in that locomotive, for great human purposes.' The idea was certainly a most striking and original one; like a flash of light it illuminated, in an instant, an entire field of science."

I have used the words, *work*, *energy* and *power*. *Work* is the effort exerted when we overcome resistance. When we walk upstairs we overcome the resistance due to the attraction of the earth, and we raise our bodies to a higher level. Work is thus done by ourselves on ourselves. When a train is moved from Liverpool to Warrington, the friction or resistance of the rails is overcome as well as that due to gravity (for we go up hill). Work is thus done by the locomotive on the train of carriages. Force has been applied, resistance has been overcome through a certain distance, and this is the measure of work expended. But this capacity for doing work must exist in a dormant state both in our bodies and in the locomotive, and this is called *energy*, which is stored up in food and in fuel, energy being simply the capacity for doing work. While the work done or energy expended is measured by the distance through which resistance has been overcome and by the weight of the object moved, the *rate* at which the *energy* is expended or the amount of work done per minute or per second is the *power*. Power is, therefore, the rate of doing work. Watt called the work expended in one minute in raising 33,000 lb. (14½ tons) one foot high a *horse power*, and this is the same as raising 550 lb. per second. A man can raise $\frac{1}{2}$ cwt. per foot per second for a short time. A horse dragging a cart of materials weighing one ton over a level road at a speed of four miles an hour exerts this power; and one of Mr. Webb's locomotives driving an express train over the London and North-Western Railway at sixty miles an hour may expend about 750 horse power. Fourteen gallons of water falling four feet per second could perform about the same work as this typical horse, and thus a horse power becomes a very convenient though rough and unscientific measure of the rate of expending energy.

Energy is expended when coal or wood is burnt, when water falls, when tides flow, when the winds blow, when food is digested; and the function of steam and gas engines, of water wheels and turbines, of windmills and of beasts of burden, is to transmit this energy to some spot where it can be utilized for the wants and purposes of man. But water is ever falling in the mountains of Wales, shining rivers flow on forever and forever, the tides ebb and flow daily in our straits and estuaries, the wanton winds expend their energies always over the surface of the land; and man neglects these stores of energy that Nature gives him at his very door.

Let us assume that we have at our command, at one spot, some source of energy, such as a steam engine or a water turbine, how can we transmit the power exerted to some other spot where it can be better utilized? Belts and shafts and ropes are at our command. A 4 in. rope, moving at a speed of 2,000 ft. per minute, transmits 8 H.P. The valleys of Switzerland abound with such conveniences. We may even lead the water itself in pipes and channels, and in America they even distribute the live steam over considerable areas. Gas is a very convenient medium for the distribution of actual energy, and since the advent of the electric light its use for this purpose has been very



ENGINES OF THE U. S. CRUISER NEW YORK.

built under the 1889 programme, which included seven cruisers and seven armored ships. The design of the New York has been described as between the British ships Edgar and Blake, which latter was recently illustrated in SUPPLEMENT 857. The New York is 880 ft. 6 in. in length on water line, 64 ft. 10 in. wide, and her designed mean draught was 23 ft. 3½ in., the displacement at that draught being 8,150 tons.

One of our illustrations shows the whole of the propelling engines in perspective, and a very long perspective they make. The ship is propelled by twin screws. As will be gathered, there are two sets of three-stage compound engines to drive each propeller. In this feature the New York resembles the Blake and Blenheim and the big Italian vessel the Sardegna. The cylinders are 32 in., 46 in., and 70 in. in diameter, and the stroke is 42 in. Piston valves are used exclusively, the high pressure cylinders having one valve each, while the intermediate and low pressure cylinders have each two valves. The high and intermediate valves are 16 in. each in diameter, but, for the purpose of balancing, the low pressure valves are made of different diameters, the mean being 29½ in. The links are of the Stephenson type, with double bars as shown. The frames which support the cylinders are of cast iron, and the crossheads run on cast iron guides bolted to the frames. The bed plates are of cast steel of I section, and are bolted to the engine keelsons, built into the ship. The piston rods, connecting rods, and other working rods are of mild forged steel. The crankshafts are also of mild forged steel, each one being built in three sections. The forward shafts are 13½ in. in diameter, with a 6 in. axial hole; the after shafts are 17 in. in diameter, with axial holes 7½ in. in diameter. There is a cast steel coupling between each

are 2½ in. in diameter. The main boiler shells are 1½ in. thick. The total main boiler grate surface is 988 square feet, and the total main boiler heating surface is 31,005 square feet. The working pressure is 160 lb. The collective horse power (including auxiliaries) is estimated at about 16,000 indicated, when the main engines are running at a piston speed of about 903 ft. per minute or 129 revolutions. Mild forced draught will be used on the closed stokehold system. The propellers are three bladed, twin screws, made of manganese bronze, and are 16 ft. in diameter with 20 ft. pitch. The two auxiliary boilers are each 10 ft. in diameter and 8 ft. 6 in. long. The grate surface for both will be 64 square feet and the combined heating surface for the two 1,952 square feet. We are indebted to *Engineering* for illustrations and the above particulars.

The contract for the New York complete was awarded by the United States Navy Department to the Wm. Cramp & Sons Ship and Engine Building Company, of Philadelphia.

ON THE UTILIZATION OF THE WASTE FORCES OF NATURE.*

By W. H. PREECE, F.R.S.

THE sun is the *fons et origo* of all the available energy upon the surface of our earth. Countless ages ago its warm and vivifying rays promoted the growth of plants and ferns and trees, which, falling where they grew, formed those great beds of coal now being brought to the surface, and which, combining with the oxygen of the air, provide us with

* Read before the Liverpool Welsh National Society and the Liverpool Engineering Society, April 6, 1892.