the retention of the phosphoric acid, but the stronger bases are more active in this regard than the weaker ones. The energetic effect of soda—formerly used in the form of nitrate in the Hargreaves and Heaton processes—has been well shown. Lime has been used as a "dephosphorizer" in many forms, as for instance chloride and fluoride of calcium. Scheerer has lately proposed the use of a mixture of chloride of sodium and chloride of calcium. A great deal of vague theorizing has been indulged in with reference to the action of these "dephosphorizers;" the dissipation of the phosphorus in the form of some volatile combination being the favorite method of disposing of it. It is, however, most probable that in those cases where basic substances have proven themselves to be of value, it is simply by the retention of the phosphoric acid in the cinder by the strong base. If this view is correct, and if the action of the Danks machine is what we have supposed it to be, then we may expect a still more favorable result in dephosphorizing pig-iron in the Danks puddler if we make the lining more active by the addition of alkalies or alkaline earths.

There can be no reasonable doubt that with a lining composed of a mixture of iron ore and lime, and possibly soda, the elimination of phosphorus would be nearly perfect.*

THE UTSCH AUTOMATIC JIG.

BY HENRY ENGELMANN, M.E., LASALLE, ILL.

ORES are generally found in the mines mixed with more or less base matter, which renders their treatment by smelting or milling unnecessarily costly. They have to be sorted. Those of a higher grade remain often mixed with substances which might, with hardly a loss of metal and at small expense, be removed by dressing machinery, and a concentrated and purified ore thus obtained, which would bring a far higher price, because it can be reduced by cheaper methods, and, at any rate, at less expense, besides affording a saving of transportation, which in our territories is often an item of no small magnitude. The ores of a lower grade have often to be

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* Since the above was written, the author has noticed that Mr. Snelus has patented a furnace lining of iron ore and lime.

entirely rejected and left on the dumps of the mines, because they cannot bear the expense of transportation and reduction. Many of these, which are raised from the mine merely because they are in the way, or are the refuse from sorting the better ores, are eminently fit to be concentrated by a proper system of ore dressing, and should be a source of wealth to their owners, instead of a worthless drug, causing only expense.

The same is true in regard to coal. Many thousands of tons of coal-slack are annually wasted because there is no local demand for it, and it is too impure for coking. With proper dressing, it would be the best article for the manufacture of coke. Almost all that will be said in the following pages of the concentration of ores will be equally applicable to the dressing of coal.

Crushing the Ore.—In order to separate the different ingredients of an ore, it is generally necessary first to comminute the ore sufficiently to set the different minerals free, to liberate them from the attached vein matter, and to break them apart from each other. This is accomplished by crushing the ore, if it is coarse and hard, first by stone-breakers and jaw-crushers, and then generally by crushing-rolls, unless the ore is to be converted into fine sand and slime, in which case stamp-mills are the cheapest and most effective machinery. One of the first rules of ore-crushing is to crush the ore sufficiently fine to set free as many of the single particles of mineral as can be done without crushing unnecessarily fine such particles as have been liberated, in other words, to crush as coarse as the nature of the ore will possibly allow.

Avoid by all means crushing too fine, because fine crushing is not only more expensive, but gives far finer sands, flour, and slimes, which require much more time, labor, and expense to concentrate, and cannot be concentrated high without causing disproportionately great loss of valuable metal, while the concentration of the coarser grains is cheap, rapid, thorough, and effected with very little loss. If the ore is of such a character, that part of the valuable mineral is coarse, and part finely disseminated through it, it is generally better to first crush it coarsely, to jig out the clean gangue and the pure ore, and to crush finer only the much-reduced quantity of such material, which consists of particles of ore still attached to grains of rock. Those not intimately acquainted with ore dressing may consider this a circuitous, complicated, and expensive system, and think that fine crushing at the first operation would be better; but an actual trial of both systems will generally result in a decided victory for the first method, as cheaper, more effective, and furnishing a more highly concentrated ore, with a considerably smaller loss of mineral. The great losses in ore concentration, of which we hear sometimes, occur principally when the ores have to be stamped fine in stamp-mills in order to free the finely disseminated mineral particles, while the loss in concentrating coarse ores should be very small under ordinary circumstances, unless an attempt is made to carry concentration farther than the nature of the ores admits. For concentrating the crushed ores, jigs are universally accepted as by far the best and most advantageous machines in every respect, unless the ores are too finely comminuted to be treated in them; in fact, jigs are so far superior to all other dressing-machines, that the best ore-dressers use them wherever possible. The automatic jig, which I here describe, unites all the excellent points of the others, and surpasses them most decidedly in the accuracy and cheapness of its work.

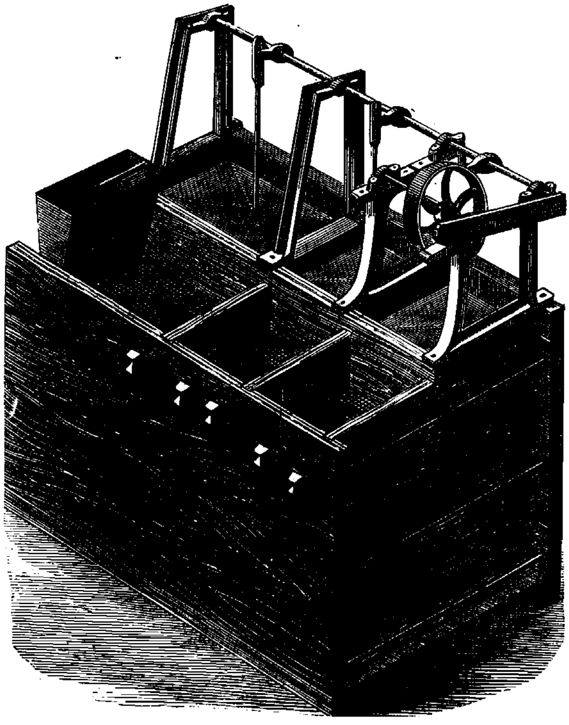
Sizing the Grain.—If only one ore of high specific gravity is to be separated from a light gangue; if, for example, cubic galena is coarsely interspersed with a gangue of calcareous spar or quartz, jigging is sometimes practiced in the old crude manner, without a previous sorting of the ore, according to the different sizes of the grains, as they come from the crusher; but when the dressing is more difficult, when, for example, blende or pyrites are associated with the galena, and especially when more than one mineral is to be dressed out and concentrated, or when the valuable mineral is less distinct from the refuse in specific weight, sizing becomes an imperative necessity. In order to effect the separation with the required nicety and precision, substances whose specific weight does not differ largely must have the single grains not only free from adhering fine sand and slime, but must be also of approximately uniform size, because the absolute weight and size, as well as the specific gravity of the single grains, makes itself felt in their treatment, in all the different dressing-machines.

The Medium.—Water as the agent for dressing ores is not likely to be ever superseded. A fluid of greater specific gravity would afford an easier separation. If, for example, we take a fluid whose specific gravity is intermediate between that of quartz and that of blende, every particle of quartz will float on it, while every particle of blende and of the still heavier galena will sink in it. Their separation will be perfect. If we then had a fluid intermediate in specific weight between blende and galena, these could be separated equally well without the use of any machinery. The difficulty of obtaining such fluids and their consequent cost precludes the adoption of such a method for dressing ores. On the other hand in a vacuum, a feather falls as rapidly as a piece of lead. The substitution of the thin and specifically light air for the heavier water, which has lately been advanced with much persistency, is therefore a step in the wrong direction, an attempt to produce a novelty which only renders an easy matter difficult. Moreover, air can only move light, that is, small grains, and air-jigs would, therefore, necessitate an otherwise unnecessary fine crushing of the ore, which in itself would increase the losses of the concentration very materially, as we have demonstrated above. Air-jigs will remain an ingenious expedient, advantageous only under the most abnormal and exceptional circumstances.

The Utsch Automatic Jig.—This is one of the latest improvements in jigging machines. It concentrates to a high degree ores which are the most difficult to separate; it does its work in an excellent manner and very rapidly, and it separates in one operation as many of the different minerals constituting the ore as it may be desirable to sort out, provided they have sufficiently distinct specific gravities. It performs a great amount of work entirely automatically, without much intervention of manual labor, requiring no adjustment or regulating for weeks and months, after having once been adjusted for an ore composed of a certain variety of minerals, although these may occur at different times and in varying relative proportions. It then works unremittingly, performing its task in the best possible manner, never missing. When the motive power stops it rests also, and resumes work without the least disturbance when the power is again thrown in gear. The relative quantity of the different minerals in the ore may change considerably; one or more of them may be almost wanting for several days together, still the machine will work on as before, with equally good results, like an intelligent being. All that is necessary is to supply it with crushed ore, and to take away the finished product which it has discharged in cars or bins. The machine thus enables the operator to dispense with all manual labor, with its expense and uncertainty. There is no need of watching inexperienced or unreliable laborers, no shirking irregularities, negligence or strikes, no holidays or pay days.

The machine does not differ in the general construction of its outer parts, and in the manner in which the power is applied, from an ordinary machine jig with plunger of the better patterns. Its distinctive feature and great excellence is secured by the manner in which the discharge of the separated minerals is regulated. This is done by pipes immersed from above in the ore bed, in which columns of the different minerals of different specific gravity and height, but of equal absolute weight, balance each other in, I might say, hydrostatic equilibrium, while discharging at different altitudes.

Fig. 5.



The Utsch Automatic Jig.

The superiority of the machine is thus due to the application of strictly scientific principles combined with the practical results of innumerable trials of the practical ore dresser. It was invented and first put in operation in Germany. After it had been thoroughly tested there, it was simultaneously patented and introduced in England and the Continental States, in Australia and America, and has met with the most universal approbation and success, because it is not only excellent in itself, but just the right thing produced at the right time—an outgrowth of the necessities of the hour. Nobody who has intelligently watched the operation of this machine can fail to appreciate its performance. In the latest pattern the pipes are directly fastened to the side of the jig, and are made easily adjustable.

In the United States it was first introduced in the ore dressing establishment of the Matthiessen and Hegeler Zinc Company, at Lasalle, Illinois. They put it on trial for several months alongside of the excellent continuously working jigs which they had in their works, which had been built after the best patterns, and were perfectly satisfactory in their performances. Nevertheless the new machine displaced them and sent them to the rubbish pile, by its palpable superiority.

We will let figures speak for themselves. At Iserlohn, Germany, the machine was first constructed, and used for the separation of an ore containing of valuable minerals, a few per cent. of galena, with some zinc blende, and calamine, which were associated with iron pyrites in a gangue of spathic iron ore, quartz, and siliceous slate. The object was to obtain the lead ore and zinc ore separately and free from the other minerals. This mixture is a peculiarly difficult one to dress, inasmuch as the spathic iron ore has not only almost the same specific gravity (3.7 to 3.9) as the zinc ores (blende = 3.9 to 4.2), but the calamine formed by the oxidation of the blende is often porous and light, while the spathic iron breaks in lamellar fragments, which are difficult to dress out. This ore had caused much trouble before the introduction of the new machine, but now, we are informed, the result is eminently satisfactory. The product is a rich galena ore and a good zinc ore obtained in one operation, while the refuse contains only a minimum of metallic matter. As an average result of two months' operation, a single jig with three sieves, with an aggregate length of 60 inches and a width of 20 inches, worked up 55 tons of raw material in ten working hours, and yielded seventeen and three-quarter tons of concentrated lead ore and zinc ore without the employment of a single laborer, except for hauling away the finished product.

At Lasalle, Illinois, the ores are partly zinc blende mixed with some galena, calamine, a little pyrites, and vein rock, and partly oxidized, and consist mainly of calamine, with some blende, galena, lead carbonate, oxide of iron, and gangue. They contain a large percentage of zinc ore, and the object in dressing them is, therefore, not to separate a few per cent. of a valuable mineral from a preponderating mass of barren rock, but to concentrate still more, and purify as much as possible an already valuable and moderately rich zinc ore; especially to free it from the deleterious admixture of lead ore, and incidentally to change the latter from an unwelcome substance, causing trouble and expense in the manufacture of the zinc, to a valuable article of commerce. The result of this concentration is, therefore, an almost pure lead ore, and a highly concentrated rich zinc ore. Both kinds of ore, the blende as well as the calamine, are worked in the new machine alternately without the least inconvenience, and without its requiring any regulating whatever when the change is made. For the last three months the machine has been working day by day, and has not required any regulating after being once properly adjusted, and there is no reason why it should not work on thus until some parts are worn out and need repairing. The raw ores at Lasalle, contain a far higher percentage of valuable minerals than those at Iserlohn, and the final product is dressed to a higher percentage. Consequently a much smaller proportion of the raw material can be discharged from the first sieve as worthless waste soon after entering the machine. From 80 to 90 per cent. of it, consisting of mixed grains and ore, have to pass further along in the machine. A far smaller quantity of raw material will, therefore, keep the machine taxed to its utmost capacity, under circumstances similar to those existing at Lasalle, than where poor, raw material is dressed. At Lasalle the jigs have, moreover, not always been fed to their full capacity. The amount of raw material worked up in a machine at Lasalle has therefore been less than at Iserlohn, but the quantity of concentrated ore obtained has sometimes run up to 19 tons of blende alone in ten working hours of one jig, varying between that number and 13 tons, irrespective of the lead ore and of the middle grades, which is returned to the fine crusher. The one machine here made five distinct divisions of material consisting mainly of:

a. Gangue and non-metallic waste.

b. Grains consisting of gangue, with calamine or blende attached, which are crushed finer.

c. Zinc blende and calamine for the zinc furnaces.

d. Grains of zinc ore with particles of galena attached, and of galena with rock attached, which are crushed finer.

e. Pure lead ore.

It thus appears that the quantity of ore which the automatic jig can dress depends, much as with other jigging machines, mainly upon the percentage of valuable ore which the raw material contains, and also upon the percentage in it of mixed grain which has to be returned to the crusher after having been separated by the machine.

It varies under these conditions between about twenty tons of rich raw material and fifty-five tons of poor raw material for ten hours work per jig. The size of the single grains of ore has a further influence upon the capacity of a jigging machine. A very fine grain retards the operation materially.

Loss.—The loss of mineral in jigging by this machine is very small, because it always does its work uniformly well and automatically, and is not dependent upon the attention of a laborer. Its construction precludes the discharge of ore matter with the refuse. Even with common jigs, when they are carefully worked, the loss is quite small, and the loss of mineral in ore dressing occurs principally in the treatment of the finest sands and slimes, which are too fine to be successfully treated with jigs, and which offer little resistance to the flow of water.

Recently the use of jigs has been extended successfully to the finest sands, which it was formerly found impossible to treat in this way, and the use of other concentrating apparatus is more and more narrowed down.

The principle upon which the automatic self-regulating discharging arrangement of the Utsch machine is founded, is that of mutually balanced columns of materials or minerals of uniform specific weight in each column, and different specific weights in the different columns. Each column discharges the surplus at once whenever an accumulation of the material composing it increases its height. A column of galena of 7.5 specific gravity and 3 inches in height, exercises the same pressure as a column of blende of 4 specific gravity and 5.62 inches in height, or a column of quartz of 2.6 specific gravity and 8.66 inches in height. They balance each other. In the jig the height of the water in each partition, and other minor conditions, enter into the calculation. If, then, the construction of the machine and the operation of jigging prevent the access of quartz to the blende column, and of the blende to the galena column, the arrangement is complete and cannot fail to operate with precision, irrespective of the varying quantities within wide limits of the single minerals.*

* In the machine represented in the drawing, the area of the sieves is divided by partitions into three compartments, communicating with each other by slots of the width of the sieves and placed immediately above them, which allow only the heaviest material on each sieve to reach the next compartment. This progress of the heavy material is facilitated by placing each successive sieve lower than the preceding one.—H. E.

If no galena is contained in the ore fed to the machine, the galena column will remain almost stationary and not discharge, but the discharge will be resumed as soon as galena is again mixed in the ore. With the other minerals it is the same. The first adjustment of the machine requires intelligent management and considerable experience; but its parts are so extremely simple that, once adjusted properly, it does not easily get out of order until some part is worn out.

Being quite simple in their construction, these jigs are very durable and need few repairs, and these can be easily executed under any circumstances, without the assistance of experienced mechanics. The sieves are made of the usual material, are solidly fastened, and not weakened by perforations or inserted pipes or slots, which always cause a premature destruction of the sieves. The discharge pipes enter the ore bed from above and do not touch the sieves. They are of the plainest form, and can be exchanged any moment if they should wear out by the attrition of the ore, which is seldom the case.

The motive power is applied in the usual manner; best by means of crank and slide. The power required for such a jig is about one-third horse-power, of course varying with the size of the grain, the different sizes requiring different lengths and number of strokes of the plunger.

The quantity of water necessary is about four cubic feet per minute per jig; for fine grain somewhat less.

The weight of the machine is that of a common machine-plunger jig of the same size, as there is nothing unusual in its general construction. The peculiar parts of it do not weigh more than a few pounds. The body of the jig can be made of wood at the place where it is to be put up.

The Utsch machine is calculated to dress ore which has previously been sorted or sized by means of sifting drums or shaking sieves, like most machine jigs, and, as is necessary in all cases where minerals difficult to separate are to be dressed out. It can be used for grain varying between 1 and 30 millimetres (0.04 and 1.2 inches) in diameter; but every ore dresser is well aware that different sizes of grain require a different length and number of plunger strokes. These widely varying sizes of grain cannot therefore be dressed together without sorting. For ordinary ores about six different sizing sieves would have to be used within these limits. For ores more easy to separate, the sizing might be further reduced; but for ores rich in precious metals and of somewhat complicated composition, the sizing should be performed in the most complete manner, in order to avoid everything that might possibly cause loss, and to be able to separate even such grains which contain only a small fragment of ore attached to a mass of gangue, or base mineral.

For an ore dressing establishment of sufficient capacity it will of course be advantageous and necessary to have a separate jig for each size of grain; but for a smaller establishment, which could not keep so many jigs in constant operation, several sizes of grain may be alternately worked on the same jig without changing anything except, perhaps, the length of stroke, which can in all cases be done easily. If the largest size of grain is not too great, even one jigging machine might suffice in this manner. The sizing drums would then have to work into bins, from which their contents would be alternately carried by spouts to the jig.

We need hardly say that the automatic jig can equally well be used for purifying coal slack for the manufacture of coke. The first discharge pipe will then yield the pure coal, the second the slate, and the third the sulphuret of iron. By actual trial, the dressing has been found excellent beyond expectation.

One jig of the size of an ore jig, as given above, I am informed, worked up in ten running hours over 1000 cubic feet of slack, equal to about 33 tons; but for dressing coal, the sieves can, without injury, be made much wider than in ore jigs. Instead of 20 inches the width can be increased to 30 or 32 inches, in which case they can dress 50 or more tons of screened slack in 10 hours per jig. In effectiveness and quality of the work done, they can therefore not be surpassed by any other similar machine.

The States of the Mississippi Valley, with all their wealth of bituminous coal and iron ores, have hardly begun to realize the importance of supplying the immensely growing pig-iron interest with a superior article of coke. For a long time it was thought that the coal of the Mississippi Valley was too impure for that purpose; but it has been proved conclusively, and on the largest scale, that these coals can be sufficiently purified. Some failures have occurred, as in most new branches of industry, a result of inexperience and mismanagement; but final success is no longer uncertain, and the new automatic jig may help to accomplish the desired result by its great efficiency and exactness of work.

The automatic jig can likewise be used for the concentration of the phosphates from the sands with which they are found mixed, and for all other purposes of separation where there is any difference in the specific weight of the substances.

Summing up the foregoing remarks, we can truly say of the automatic jig that it does better work than other jigs, effects a closer dressing, enables us to separate in *one* operation, with great precision, any number of different minerals differing sufficiently in specific weight, dispenses with all manual labor, does, therefore, cheaper work, is durable and simple in construction, and is equally effective for dressing ores, coal, and other substances.

SUPPLEMENT.*

At the last meeting of the Institute I placed before its members a description of a new jig with automatically regulated discharge, the invention of Mr. Utsch. This paper has created some discussion in the journals; and I believe it will be interesting to many to have some numbers and facts in regard to this matter, taken from the actual results of the ore-dressing works of the Matthiessen and Hegeler Zinc Company of Lasalle, Ill., who were the first to introduce this machine in the United States.

The ores treated in these works are partly blende, partly zinc carbonate, obtained mainly from numerous mines of the lead region of Wisconsin. They all contain some lead ore, besides pyrites, rock, etc. All paying quantities of galena are separated from the ore by the miners, and only such is left as the miners cannot separate in the ordinary Cornish jigs, or without too great expense. The ores thus retain on the average 3½ per cent. of lead, according to analyses continually made. This lead is partly in the form of galena, partly oxidized, and then frequently intimately mixed with the zinc ore, so that mechanical separation is impossible, and it cannot even be detected by the eye. The average quantity of raw ore dressed per month has been over 2,100,000 pounds during the last twelve months, the running time being ten hours per day.

By far the largest portion of these ores (about 85 per cent.) are submitted only to one operation of the jigs; the raw ore is not a poor ore on the average, although part of it is low grade. The coarsest grain passes through a screen with holes of 15 millimetres (⅗ inch) diameter. When ordinary coarse ore is being treated about 82 per cent. of the ore is obtained in grains between 15 and 1 millimetre

* Read at the Easton Meeting, October, 1873.

($\frac{3}{5}$ and $\frac{1}{25}$ inch) diameter, which are washed on four different Utsch jigs. Of the remaining 18 per cent. under 1 millimetre diameter, 8 per cent. forms the two coarsest classes of sand, and is treated on an Utsch fine-grain jig, with 120 strokes per minute. Notwithstanding the low percentage of lead in the raw material, this also gives pure galena and workable zinc ore in the first operation. The remaining 10 per cent. of the ore is divided between the finest sand, flour (of which two classes are separated), and slime. The flour is treated on a fine-grain jig with 300 pulsations or strokes per minute; and even more might be applied advantageously for such fine material. The idea that water-jigs cannot be worked so rapidly is entirely groundless; only coarse grains require long, strong, and not too rapid plunger-strokes, and thick layers, while fine grains require numerous, rapid, and minute pulsations, and thin layers.

The galena from fine flour is not concentrated in one operation. It could readily be done if the percentage were higher. At present the object is to obtain as good a zinc ore in the first operation, and as much of it as possible. A recent analysis gave the following results from this jig.

The raw flour contained	3.50	per cent.	lead.
The first partition of the jig	21.99	"	"
The second partition of the jig	1.98	"	"
The third partition of the jig	2.11	"	"
The fourth partition of the jig	2.39	"	"

The percentage of zinc is highest in the second partition. This result is curious, but easily explained. All the coarser flour of lead is obtained in the first partition. In the other ones we find either such particles of lead ore as cannot be separated mechanically from the zinc ore (carbonate of lead combined with carbonate of zinc), or particles of such extreme fineness that they float, and belong more properly to the slimes (*todtgepochtes*—"dead-crushed" lead, as the Germans call it). The contents of the first partition of this jig are concentrated in one more operation.

The remaining 5 per cent. of the ore are slimes, which may be dressed on buddles, etc., and frequently will not pay for concentrating at our prices of ore, labor, etc., because they yield an inferior product.

Of the $3\frac{1}{2}$ per cent. of lead in the ore, on a large average the loss in lead is 2 per cent. of the raw material—40 pounds per ton of ore treated. In this case scarcely 50 per cent. is saved; but the loss would not be much greater in weight of lead if the ore contained 30 or 50 per cent. of it. Part of this loss is caused, as I have stated, by the chemical combination, or rather the mixture of the carbonates. Another portion is caused by the insufficient mechanical separation of the galena from the zinc ore, and by the imperfection attending all operations on a large scale, especially those depending to a certain degree upon manual labor—in this case upon the regularity with which the crusher is fed. It is not advisable in this instance to crush the ore finer, because the coarse jig-stuff is, after all, richer than the finer. The loss of zinc ore in this concentration is very small.

I have stated actual facts—actual working results—including all disturbances, irregularities, and troubles of regular operations. They are not made-up returns. The percentages of lead are determined by often-repeated chemical analyses. Fire assays would be entirely inadequate under such circumstances, and the eye cannot detect the lead in many instances where the analysis shows its presence.

THE COMPRESSION OF AIR.

BY PROF. B. W. FRAZIER, LEHIGH UNIVERSITY, BETHLEHEM, PA.

At a recent meeting of the North of England Institute of Mining and Mechanical Engineers, during a discussion upon the compression of air, attention was called to an apparent anomaly in the phenomena attending the compression. At a subsequent meeting this apparent anomaly was explained by Prof. Herschel, and all the facts observed shown to be strictly in accordance with the laws of thermodynamics.

Upon reading the report of the discussion in the published transactions of the society, it occurred to me that an attempt to determine mathematically the amounts of energy (whether in the form of heat or of work) expended and absorbed in compressing air, and causing it to perform work by expansion, might prove of use to some who have not access to any treatise upon the application of the laws of thermodynamics to the compression of air, and who have not the time or the inclination to make such application for themselves.

The apparent anomaly noticed was this: If air be compressed, and at the same time, by the sufficient application of a cooling medium, kept at a constant temperature, the indicator diagrams in the