GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT ON

COAL WASHING

FOR THE

SEPARATION OF COAL FROM ITS IMPURITIES.

BY P. N. MOORE.

PART III. VOL. VI. SECOND SERIES.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

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COAL WASHING FOR THE SEPARATION OF COAL FROM ITS IMPURITIES.

Kentucky, fortunate in her great coal fields, possesses vast stores of excellent coal which is so pure that it can be used for iron making without further preparation; but, in comparison with the whole coal field, the deposits of this class are limited. The State furnishes no exception to the general rule, that where there is much that is good there is more that is indifferent or poor, and she possesses still greater quantities of coal which is unfit for use in iron making, and ranks low for general purposes.

It is useless to deny this fact, for it is well known, and the markets of the State acknowledge it in the prices at which many of the coals above referred to are sold. It is wise, therefore, frankly to acknowledge the unpleasant truth, and to strive, by superior skill in the manipulation and preparation of these coals, so to improve them that the disadvantage of quality may be overcome. It is only through such efforts that mining of many of the coals even now accessible to transportation can be made profitable, and it cannot be expected that new fields will be opened while those already open are not worked at a profit.

The eastern coal field, while possessing the best iron making fuel in the State, a coal of most excellent quality, and as widely as it is favorably known, and while, in its undeveloped portions, holding many coals which promise equally well, still has extensive deposits of coal of good thickness, and favorably located to transportation, which cannot now be utilized on account of the impurities of the coal, but which, could these be removed, would become available and a source of great wealth.

The western coal field, unfortunately for itself, in conformity with the general law of the coal fields of the United States, that the coals, as a rule, grow inferior to the westward, holds a greater proportion of these inferior coals. This is so far true, that the poor coals are the rule, and those of moderate purity the exception. Thus far, unfortunately, all attempts at the utilization of the western coals in any branch of iron making have been unsuccessful. No coal pure enough and of suitable structure to use in the furnace without coking has been found, and the great stores of iron ore of the Cumberland River Ore District, which lie so close to the western border of the coal field, a situation the most favorable for the building up of a great iron industry, have only been utilized to a very small extent with charcoal, while the establishment of the industry which these fuels and ores are so capable of supporting, and which is destined to enrich this end of the State, awaits the introduction of new processes, or apparatus by which the coals can be made available. The only solution possible to this question seems to lie in the washing and subsequent coking of these coals, by which a fuel should be produced pure enough for iron making.

There is no question of more importance, none with a more vital bearing upon the future manufacturing prosperity of Kentucky, than that of the utilization of these coals, and the establishment of a permanent iron industry in the western part of the State; and no further explanation should be needed for introducing a subject so strictly technical into the Reports of the Geological Survey.

Under the stimulus of the severe competition resulting from the immense development of the manufacturing industries of the world during the past decade, and the succeeding, long continued financial and business depression, it has become necessary, in all establishments, to practice the utmost possible economy. To this end, manufacturers are constantly endeavoring to lessen the cost by improving the quality, or decreasing the quantity of their fuels; and the question of the utilization of poor coals, heretofore considered unsuitable, is receiving some attention in this country and much more in

Europe, where coals of excellent quality are not found over so widely extended an area as here.

Such efforts have taken two directions: one, the invention and construction of furnaces peculiarly adapted to the consumption of the coals as they are, without further treatment; the other, the purification of the coal from its objectionable ingredients, which are, generally, pyrites, slate, and clay.

Efforts in the first direction have resulted in the introduction of regenerative or gas furnaces, which are very successful, and for many purposes all that can be desired. By them, fuel of almost any character can be used for the production of very high temperatures, and less fuel for a given result is required than in any other style of furnaces; but the first cost of these furnaces is often so large that it prevents their introduction, and there are also many purposes for which they are not well adapted.

It is, therefore, to the efforts in the second of these directions or processes for the purification of coals that this paper will be devoted, and some description of a few of the most recent processes and apparatus in use in this country and Europe, for this purpose, will be given.

The most common impurities of coal are iron pyrites and slate or shale. In some cases sulphate and carbonate of lime occur, and also a considerable amount of clay, apparently washed into the seams of the coal from above. The pyrites and sulphate of lime furnish sulphur, while the effect of all is to add greatly to the amount of ash. Where these are present, therefore, in considerable percentages, it is evident that the coal cannot be used raw in the furnace for the manufacture of iron, neither can it be coked, even if it be a fat or caking coal; for while the operation of coking expels a large part of the sulphur by its removal of the volatile matters, it concentrates and increases the percentage of ash, so that the coke will contain, on an average, at least fifty per cent. more ash than the raw coal from which it is made.

For general manufacturing purposes, such as the production of steam, while it is not impossible to use impure coals, they are still very objectionable, as the heating power of such coals is low, and the quantity of ash and clinker troublesome and expensive to remove. To the manufacturer or iron maker, every additional pound of ash which his coal contains is a source of expense—small, it may be, but yet in the aggregate great, and of importance in times like the present, when the most rigid economy is demanded in every branch of business.

The task of separating the slate, pyrites, and other impurities from coal, has as yet only been successfully accomplished by washing. The separation is due to the difference in specific gravity between the coal and its impurities, and the different rates at which particles of the same, or approximately the same, size, but of different specific gravity, settle in currents of water moving vertically or horizontally.

The processes all involve the one objectionable feature, that they require the reduction of the coal to a comparatively small size, the fineness depending upon the intimacy of the admixture of the impurities with the coal. This is a serious but unavoidable disadvantage of all the methods; for in no other way can the desired result be effectually accomplished, since the intermixture is usually quite intimate; where it is otherwise, a careful hand-sorting is generally all that is required. The importance and trifling cost of even hand-sorting does not seem to be properly appreciated by the managers of Kentucky mines.

With properly constructed screens and tables, and the use of boy labor, hand-sorting costs but a trifle, and it adds greatly to the value of the coal. It is safe to say that much of the prejudice which prevails in the Louisville markets against Western Kentucky coals would never have existed, had the colliery managers attended properly to the screening and sorting of the coal before it went to the cars.

The necessity for reducing the coal to a small size is no objection, but rather an advantage, where the coal is suitable for coking, and is used for that purpose, for it is better pulverized. But this process has, heretofore, with us, confined the use of washed bituminous coal to that purpose. In the anthracite regions of Pennsylvania, however, washing machinery is coming more and more into use for the removal of slate, and it is superseding, to a considerable extent, the old methods of hand-picking, as it is found that the smaller sizes of coal, which have been washed, are freer from slate than the larger sizes which are only hand-sorted.

In Germany, however, at many mines of bituminous coal, where the coal contains much slate, the washed fine coal of various sizes, except the very finest, is sold for manufacturing purposes, and brings a price which fully repays the operation of washing. There, however, the fine coal, as it comes from the mine, contains as much as from 20 to 25 per cent. ash, and the coal seam is so disturbed and crushed that a large amount of fine coal is obtained in mining, often as much as 60 to 70 per cent. of the total output. In this case, it becomes a matter of the most vital necessity to utilize the fine coal or slack, otherwise so large a proportion of the product would be lost that the mines could not be profitably carried on.

It is probable that at many of our western mines, such of them, at least, as are large producers, even where the coal is too dry for coking, it will be found profitable to wash the slack, which is now either thrown away or sold for a trifling price for steam firing. The slack is usually more impure than the lump coal, as the slate and clay from the roof and floor become mixed with it in the handling it undergoes. The additional price which can be obtained for it, if it were washed so as to reduce the ash to 4 or 5 per cent., will probably more than pay for the washing, and it will have a more ready sale.

Where the coals are dry or non-coking, the above uses will probably, for the present, limit the introduction of washing machinery; but where they are fat or coking coals, its use will probably become almost universal; for the washed coal will make far better coke than the unwashed, and the demand for coke is becoming almost as extensive as for coal itself.

Without doubt, the use of coke as a metallurgical fuel is increasing, and destined to a yet greater growth. Its advantages over the best raw coal are so great, that attention is being more and more turned to its production, and attempts, with more or less success, are made to produce a coke from the dry coals of the Mississippi Valley. It is probable that success will yet reward these efforts; and in that case, the use of washing machinery will be still further extended, and we shall see, as in some of the European coal fields to-day, every colliery equipped with its washing machinery and coke ovens. Increasing competition will doubtless compel this; for, by such complete equipments only, every portion of the mine output can be disposed of to the very best advantage. With such an outfit, the colliery can produce, on demand, the cleanest lump coal, washed nut and slack, as well as coke. The separation into different sizes, as in the anthracite coals, though doubtless not carried to anything like such an extent, will probably also follow, and all of the smaller sizes will be sold as washed coal; while the lump and the sizes of nut coal too large for washing, will be subjected to a careful hand-sorting by the use of traveling tables, upon which the coal falls from the screens and is carried along past boys, who sit upon either side, and pick out the pieces of impure coal, slate, and pyrites.

No matter what its reputation, what its nominal purity, there is almost no coal used for coking which will not produce a better coke if it is previously washed. The common expression, "free from slate and sulphur," is founded on enthusiasm rather than fact. There is no coal which does not contain an appreciable, and usually a considerable, percentage of these injurious ingredients, and which cannot be freed from them, to a large extent, by properly conducted washing.

The colliery proprietor, who contemplates the erection of washing machinery, will find the cost of the operation, for a given quantity of coal treated, distributed under the three following heads:

(*a*). Sinking fund and interest upon capital invested in the machinery, &c.

(*b*). Operating expenses, including labor, superintendence, repairs, &c.

(*c*). Waste or loss of coal in washing.

This loss increases with the original impurity of the coal and the unskillfulness of the operation. If properly conducted, little should be wasted with the slate and pyrites washed out; but, of course, the product of washed coal is less by the amount of impurities removed.

Where the coal is purchased for washing, or where the miner is paid for the fine coal, or, in other words, where the coal to be treated is anything but a waste material for which nothing is paid, this item must be as carefully estimated as any other.

These items are all subject to great variation with the peculiar circumstances of each colliery; but, given the details in each case, they are susceptible of close and accurate calculation by any competent engineer.

Upon the credit side of the operation is but the single item of increased price for an improved product of less quantity than the raw material. Into this item all the advantages of improved quality, wider sale, increased availability of coals otherwise unmarketable, &c., heretofore cited, resolve themselves. From the nature of the case, this is not always so susceptible of exact calculation as the estimates of cost; for the most experienced cannot always tell what will be the future course of a market for any product. It belongs, partly, among those subjects which the trained judgment of the keen business man must often decide, without being able to give the detailed steps by which the decision is reached. Nevertheless, when the character of the coal is well known, the amount of daily product, the usual market, and all the local circumstances of the colliery, it can be estimated with sufficient accuracy.

As a rule, the introduction of washing machinery is only advisable, when it has been shown, by the most careful investigation in each particular case, that the profit will more than equal the various items of cost; but there may be circumstances where it would be advisable to construct such machinery though the increased price of the product be barely equal to the cost, when, by so doing, a colliery can command a better sale for portions of its output, which otherwise would be troublesome to dispose of, or not involve actual loss, or when it is enabled to occupy or retain a market that would otherwise be lost. Such a case, of course, is really profitable to the colliery; for, although there may be no gain on the washed coal sold, the indirect advantages are very great. It is probable that such conditions will be more and more prevalent in the future.

The above reasoning is based upon the supposition that the washed coal is sold to coke works or other market. In reality, however, in a large proportion of cases, the colliery, coke works, and furnaces which consume the coke, will all belong to the same owners, and washing apparatus will be introduced rather for the improvement of the coke and the consequent less consumption of fuel and improved working of furnace and quality of iron made, than for direct profit to the colliery. In reality, however, it amounts to the same thing, and the profit of the operation can be calculated back to the basis of the coal washed.

It has been shown above that the cost of removing the impurities from coal, by washing, varies with any one of three elements, since it is the sum of the three. It is, of course, the endeavor of the proprietor or manager to reduce this cost to the lowest possible limit. It is for him to consider, therefore, in the selection of a system of coal washing at any given place, that he has three directions, in each or any one of which he can economize, and that saving in the total may often be effected by a reduction in one or two of them, and an increase in the third. There can be given no general rules for such cases. Each locality must be a law unto itself, and the local circumstances, such as cost and quality of coal, market, product most in demand, supply of capital, cost of labor, etc., must decide what system is, for that place, the most economical. For instance, where coal is plenty and cheap, capital scarce, and interest high, and the product of coal to be washed limited and irregular, that system of apparatus or machinery is most economical which requires the least investment of capital, even if it does involve the waste of a considerable amount of coal in the endeavor to obtain a clean product. Such a system may be an imperfect one, but it is not necessarily an expensive one.

On the other hand, where capital is plenty and interest low, while coal commands a good price, and the colliery furnishes regularly a large amount of coal to the wash apparatus, the most perfect machinery which wastes a minimum of coal, and washes with the greatest efficiency, is the most economical, even if its first cost be large.

Having seen something of the necessity and use of coal washing machinery, and having discussed the circumstances under which it would or would not be advisable to introduce such machinery, we come now to the subject of the various systems and apparatus for the removal of the impurities from coal. As before stated, these all accomplish the result through the agency of water acting in a great variety of ways. As yet, though it has been proposed, the substitution of air for water, as a concentrating medium in coal cleaning, has not been successfully tried, and it is doubtful if it ever will be successful. It certainly can only be used, if at all, for the fine or dust coal, and this fact will forbid its use except in very isolated cases.

The number of systems, and the variety of machines which have been used in coal washing, is very great, and it is far beyond the limits of this paper to attempt a description of even one half of them; nor in a practical discussion of the subject would it be of any service, for the great majority of them are old-fashioned, and have been superseded by improved apparatus, and descriptions of them would possess no practical interest. It is true that many of these are still in service, but it is only at the older establishments, where they were built before the improved machinery was introduced. It would, therefore, possess only an historical interest to describe machinery which no one would think of erecting at the present time.

The scientific principles of ore dressing, which have been so elaborately developed through mathematical reasoning and careful experiment by foreign writers upon the subject, are, of course, the same which govern coal washing, and the same laws of classification hold; but, in practice, there is a difference; for, in ore dressing, it is the heavier product which is usually the valuable one, while the lighter is the waste, and all the apparatus, therefore, is calculated for saving the heavier portion of the ore and the rejection, with the least trouble, of the lighter. In coal cleaning, on the contrary, we have the objects of the same operation directly reversed, and the heavier slate and pyrites are the waste, while the lighter material, the cleaned coal, is the valuable product. The operation, of course, in both cases, is the same—that is, the separation of a heavier material from a lighter; but the different object renders necessary some changes in the construction of the apparatus.

Discarding, for the present, a variety of systems which belong to the past, although locally still in use, and others which are still too untried to determine the place they will fill in the future, we have worthy of description, as having proved, by actual trial, their success, and as being now in most extensive use at home and abroad, the following systems of coal washing, classified according to the manner in which the water acts:

I. Where the material to be washed is subjected to a horizontal, or nearly horizontal, constant current of water, the material being submerged in the water, carried along by it, classified, and deposited at the bottom of the stream in accordance with the size and specific gravity of the different particles. This class embraces all the trough or sluice washers, which will be described more in detail further along.

II. Where the material to be separated, resting upon a sieve or screen, is subjected to the action of upward, intermittent, quick currents of water, the water coming from below, lifting the whole material and then allowing it to settle and separate in the interval between the strokes. This class embraces all the great variety of machines called jigs, in which the motion to the water is given by a movable plunger, while the sieve upon which the ore to be separated is placed remains fixed. The number of jigs which have been invented is very great, and constantly increasing; they differ widely in detail, and are of greater or less excellence; but they have the above principle, which is characteristic of the modern power jig, in common.

The above classes comprise, probably, more than nine tenths of the apparatus for coal cleaning at present in operation; but there are other systems, which have been used only to a limited extent, which promise well for the future. There are, therefore, perhaps, worthy of description, the following additional systems:

III. Where the separation is effected by a constant upward current of water acting against the falling particles of the material to be separated, the current being so regulated that the heavier material falls through it, while the lighter is carried over by the stream of water to a proper receptacle. To this class belong the so-called syphon washers, in which the upward current is maintained at a constant velocity by a head of water, and the Day washing machine, in which the upward current is produced by two propellers, rotating in opposite directions.

IV. Where the material is separated by falling into still water, and by subsequent upward, intermittent currents of water, induced by a pressure of steam in another part of the apparatus.

The only apparatus of this class is known as the Evrard coal washer.

In all of the systems above referred to, the completeness of the separation depends largely upon the proper sizing or classification of the coal before it goes to the washing apparatus. As a rule, the more careful the sizing, the more complete the subsequent separation; and, for the most satisfactory work, only one size will be submitted to any given piece of apparatus at one time. It is possible, however, to effect a separation of coal from its impurities without this careful sizing, but it is done at the expense of a somewhat greater waste of coal, or a larger percentage of impurities remaining in the washed product. This sizing or classification is done by screening, and, of course, every additional screen necessitates other machinery, and thus adds materially to the cost of separation.

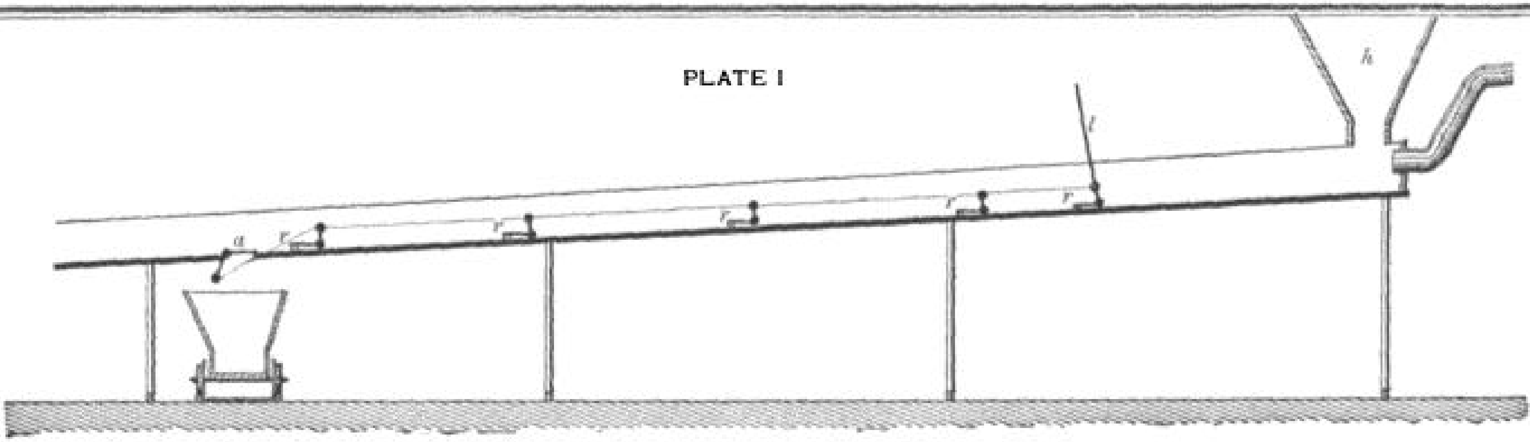
Here, again, therefore, as in the decision as to the apparatus to be employed, there must be a choice between the alternatives of a more perfect operation with larger outlay and greater saving of coal, or a less outlay and greater waste of coal.

Coming now to the description of the apparatus of the different classes in most general use, we have:

CLASS I. SLUICE OR TROUGH WASHERS.

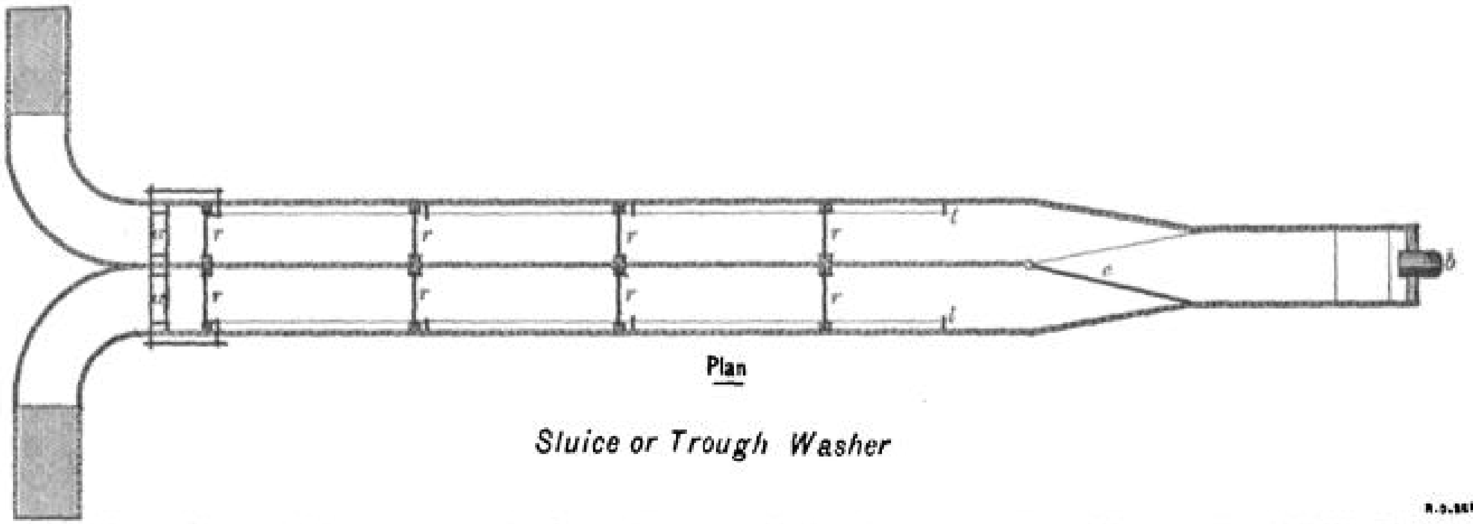
This style of apparatus is, at once, the simplest, the oldest, and the cheapest of all forms. It consists of a wooden trough, furnished at proper intervals with movable riffle bars to interrupt the force of the stream, inclined at an angle sufficient to produce the proper force of current to carry the coal along, while the heavier slate and pyrites are deposited in the bottom of the trough above the riffle bars. The accompanying figures, Plate 1, of the double trough washer, in most common use in the Lancaster and Durham coal fields, England, will sufficiently illustrate its operation. The fine coal or slack comes from the screens directly to the feeding hopper *h*, whence it falls into the head of the trough, meeting the stream of water, which is often the waste water from the mine pumps, introduced by the pipe *b*. The impurities being heavier, sink to the bottom of the stream and are interrupted by the riffle bars *r r*, while the coal is washed along to the end of the trough, over a drying screen, into a proper receptacle. The larger lumps of coal, of course, tend to lodge with the impurities, and to prevent this, they are stirred with a rake, by the attendant, from time to time. When the space above the bars becomes filled with slate so that they no longer interrupt the current, the hinged gate *c* is thrown to the opposite side, and the current turned into the other channel. Then, by means of the lever *l*, the riffle bars and the trap *a* in the bottom of the trough

PLATE I



Elevation

Sluice or Trough Washer



Plan

Sluice or Trough Washer

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are raised, and the slate is washed out through the opening into the car placed to receive it. By this reciprocating action the washing goes on uninterruptedly. An apparatus of the size figured, 2 feet 6 inches wide and 40 to 50 feet long, requires to attend it two men, and will wash from 175 to 200 tons of coal in 10 hours. This does not, of course, include the labor of removing the washed coal and the slate. By using a rake, or stirrer moved by machinery where the washer is located near available power, the labor of one man can be dispensed with. The total labor, under the most unfavorable circumstances, should not exceed six or seven men for 200 tons of coal per day. Estimating these at $1 25 per day, the maximum cost per ton, for labor, will be 4.37 cents. The other expenses for washing by this system are not great.

At the Tursdale Colliery, Durham, England, belonging to Messrs. Bell Brothers, this system is in use, washing about 400 tons per day. The writer was informed that the coal, as it came to the wash, contained from 12 to 15 per cent. of ash, which was reduced to 4 or 5. The cost of washing was given at 6 pence to the ton of coke produced, or about 3½ pence (about 7 cents) per ton of coal, the yield of coke being 57 per cent.

This system of washing has great advantages, in that the cost of the apparatus is very little; that it is exceedingly simple; that the expense of repairs is almost nothing; that it is always in order and ready for operation; that it requires no machinery except a pump to supply the water—in some cases a separate pump is not even needed, and that it uses comparatively little labor.

It is open to the objection that it requires a large amount of water; that, as there is no previous sizing of the coal, the washing is either imperfectly done, and all the impurities are not removed from the coal, or else, if the coal be thoroughly cleaned, much will be wasted with the slate, and that the operation is peculiarly dependent upon the care and watchfulness of the workmen at every step, so that the slightest negligence on their part will show itself, at once, in the higher percentage of ash in the washed coal.

It is also probable that, in some parts of our country, it would give trouble by freezing in the winter time.

This style of apparatus is that in most general use for coal washing in the Lancashire and Durham coal fields of England; but the great majority of the collieries in those fields have, as yet, adopted none at all.

After the above summary of the advantages and disadvantages of the apparatus, it is necessary to say little more concerning it. It cannot be called a perfect apparatus, and does not give the finished results of the more elaborately designed and complicated systems; but it is very efficient, and can be erected at so trifling a cost that it is to be recommended for all those collieries where there is an ample supply of water and a scarcity of capital. It is advisable, also, as an experimental washer, where it is uncertain what will be the sum of the advantages to be gained by purifying the coal. With it the experiment can be tried, and afterwards, if desirable, more complete and perfect machinery erected.

It is to be noted, too, that it is capable of doing better work, if the material were to be previously sized, as in other systems; but the addition of screens would increase the cost very materially, and thereby lessen the advantages which it possesses over others.

The efficiency of the sluice washer decreases rapidly with the increasing impurity of the coal to be operated upon; so that, with very impure coals, it will no longer be an economical apparatus, for the necessary waste of coal will be excessively great. It is best adapted to coals with not exceeding 15 per cent. of ash.

In using this apparatus, the length and inclination of the trough and the number and size of the cross bars, is to be determined by the character of the coal. Where the impurities readily separate, the pitch may be made steep and the trough short; where they are slow of separation, the inclination must be more gentle and the trough longer. A very common slope is one inch to the foot. The height of the riffle bars must depend upon the depth of the stream of water which flows over them. While they must be high enough to thoroughly check the current of water, they must not be so high as to prevent the coal from being carried over. Three inches is an average height, with an interval of from six to ten feet between them.

CLASS II. JIGS.

We come now to the apparatus of the second class, where the material is subjected to the action of upward, intermittent currents of water, which currents are produced by the action of a wooden or metal piston, or plunger moving up and down in a closed compartment. Machines of this class are called jigs. They are the best known and most universally applicable of all machines for the separation of ore or coal. The method of operation is identical in all of them; but there are many, very many, modifications of details, and each jig, with some peculiar modification, is known by the name of the inventor. In all of them * the material to be treated rests upon a screen or sieve, and the plunger forces the water from below through the mass, which, as the water slowly settles, rearranges itself in layers composed of the different minerals of different specific gravities, the heaviest at the bottom and the lightest at the top. In some jigs; the plunger works directly under the sieve; but, in the great majority, the machine is divided in two compartments, in one of which the sieve is placed and in the other the plunger moves. There is a partition between, which only extends downwards a little below the limit of the plunger stroke; all below is open, to allow of the free movement of the water. The material upon the sieve is usually only a few inches—from six to ten—in thickness, so that the jig only acts upon a small quantity at one time. The thickness decreases with the size of the material treated. In order, therefore, to accomplish the greatest result,

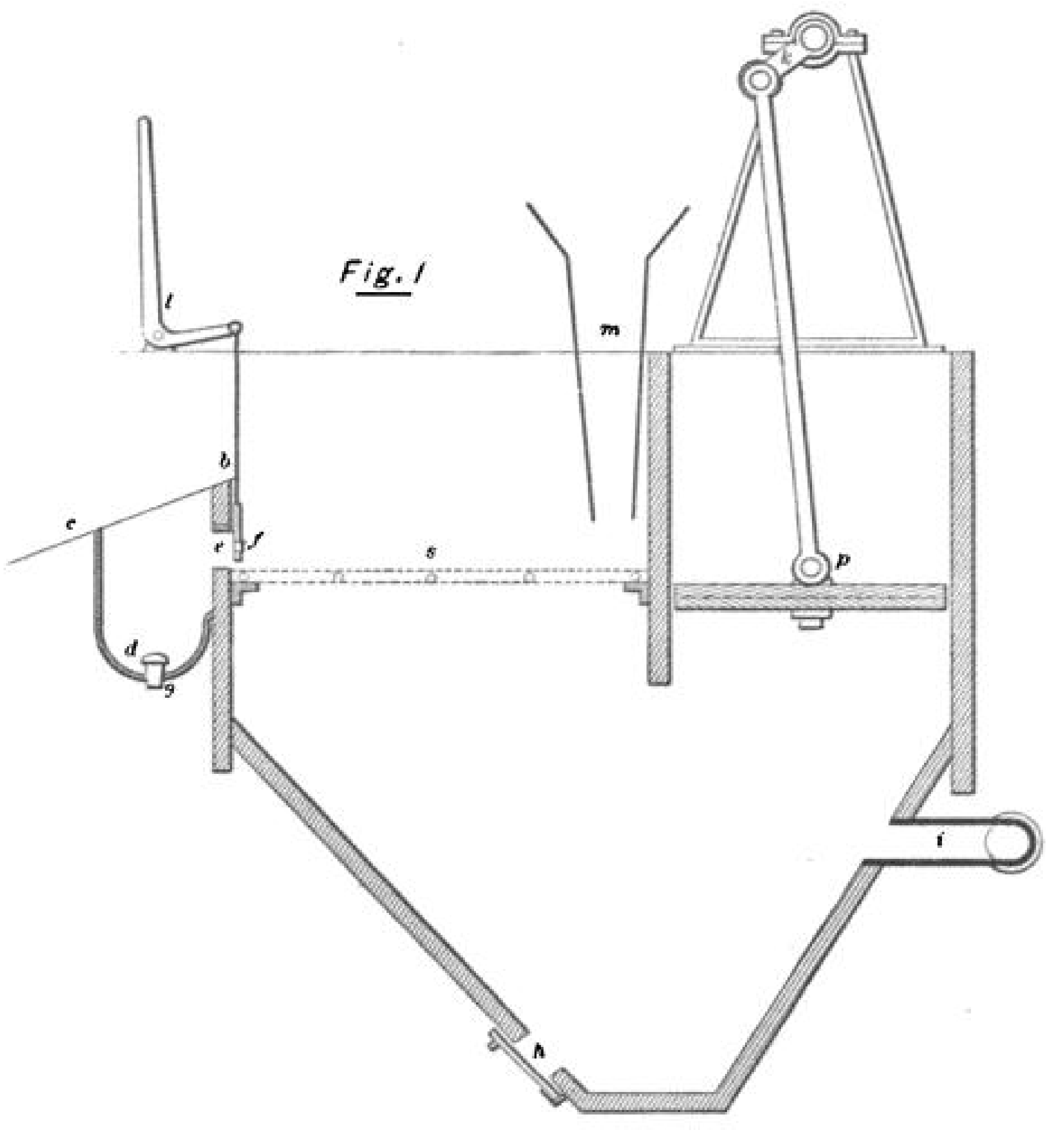
* It is understood here that the modern machine jig is alone referred to. The old-fashioned hand-jig moved the material up and down in still water and was a very different piece of apparatus. It is, however, rarely constructed at present.

it is arranged so that the unwashed coal is automatically fed to the jig from a hopper, as fast as the machine can dispose of the washed coal and the separated slate. A classification of the material to be washed into grades of similar, or as nearly similar size as possible, is a prerequisite to the most successful separation by jigs. This is of more importance in ore dressing than with coal; but still, it is with coal essential to the most perfect work.

There is, of course, an economical limit to this, which is soon reached; for a greater number of sizes necessitates an increased number of jigs and increases the waste of coal, in the form of dust, as it is so friable that each additional screening adds materially to the fine coal. With small washing establishments, this limit is soon reached; but the greater the amount to be daily treated, the more numerous can be the sizes into which the coal is separated. The sizes which can be most successfully treated in an ordinary jig vary from 4 m. m. (0.15 inch) to 25 m. m. (0.98 inch). Below 4 m. m. (0.15 inch) the coal is practically a dust, which is much more difficult to separate successfully, and requires to be treated on jigs of peculiar construction. Coal as large as 40 m. m. (1.57 inch), or even 60 m. m. (2.3 inch), is sometimes jigged; but it is better either to crush it to a finer size, or to remove the impurities by hand-picking. The limit of size depends chiefly upon the structure of the coal and slate bands. If they be finely banded in thin layers, the size for jigging must be much less than otherwise. In some cases, it is found necessary to reduce everything to 15 m. m. (0.59 inch), or even less, as at the Meier Coke Works, in East St. Louis, Illinois, where washing the coal from Belleville, the best maximum size was found to be 11 m. m. (0.42 inch).

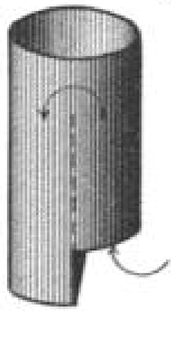
One of the oldest and simplest forms of jig for coal washing is that known as the old Hartz jig; a section of one is shown in Plate II, Figure 1. Motion is given to the plunger *p* by the crank *k*. The coal falls through the hopper *m* upon the screen *s*. The hopper is placed at the back of the screen, so that the coal must travel the full length of the screen before

Fig. 1



Old Hartz Jig

Fig. 2



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it passes from the jig. The cleaned coal is washed by the water over the dam or bridge *b* upon the drying screen *c*, whence it falls into a channel, and is removed by an endless screw or elevator. The slate and pyrites pass through the opening *c* into the trough or channel *d*, whence it is removed, from time to time, by opening the valve *g*, at the bottom. This valve is raised by a lever not shown in the drawing. The size of the opening for the discharge of slate is regulated by the slide *f*, moved by the lever *l*. Water is supplied through the pipe *i*, and the fine coal, slate, &c., which fall through the sieve, can be removed through the opening *h*. The above description and the figure are intended to give only a general idea of the working of this machine; but, of course, they possess no accuracy of detail. The details of the machine can be, and are, varied in very many ways, as the circumstances of the case demand. The box may be constructed of wood or iron, and in section it may be rectangular, semicircular, or as shown in the figure; but, of whatever material, it must be strongly built and firmly tied together, as it must resist severe and constantly repeated shocks. At each stroke of the plunger, a strain is thrown on every part of the machine; and, since this is repeated many times a minute, if the machine be not strongly built, it will soon be racked to pieces. It was long ago discovered that the above described machine possessed serious defects.

It was found that it could not be run at the highest speed, and was consequently limited in the amount of work it could do, as if speeded high, suction was likely to be produced by the return stroke of the plunger, and this interfered seriously with the free separation of the different particles upon the screen. The object of the stroke is, as suddenly as possible, to lift the whole mass upon the screen in the rising stream of water, and then, as the current ceases, to allow the material to settle and rearrange its particles in accordance with their density. If, however, there be a downward return current as strong as the upward, this separation is seriously interfered with. To prevent suction by the upward movement of the plunger, a variety of methods have been tried, with results successful enough to secure the use of some or all of them in most of the jigs now constructed.

The plunger is now no longer made solid, but with valves which open to let the water pass through with the rising stroke, but close with the beginning of the downward movement. The feed water is also supplied through a large pipe, and, if possible, with a small pressure, so that the water to supply the place of the rising plunger will naturally flow more readily and easily from the feed pipe than back through the layer of coal. Valves are also arranged to assist this result.

In order to give a quick stroke and a slow return, the plunger is sometimes made very heavy; a slow upward movement is given to it by a cam, and then it is allowed to drop of its own weight. This is effectual when treating coarse stuff, where it is not necessary to use a very rapid stroke.

Another important improvement in this direction is the slotted arm, by which a quick motion is given to the downward stroke and a slower movement to the return. By this arrangement the crank pin of the arm, which is moved by the main shaft, is not connected directly with the plunger, but slides in a slot between guides forming another arm, which in turn communicates the irregular motion thus received to a second shaft and lever connected with the plunger.

This very successful invention is used on some of the best modern jigs, among them, those known, from the names of the patentees, as the Lührig and the Osterspey, and the jigs built by the celebrated Humboldt Company of Kalk, near Cologne.

Another very serious, perhaps the most serious objection to all of the old style of jigs, was, that they were more or less intermittent in their action, requiring constant supervision, an occasional stoppage to clean out, and always the intervention of the attendant to discharge the slate receiver of its contents. Often the discharge of the washed coal over the bridge or dam gave trouble, and some sort of a mechanical rake or scraper was added to carry it over; and where the coal was impure, and the quantity of slate and pyrites to be discharged large, constant attendance was needed to keep the machine in good work. The attention of manufacturers and inventors, therefore, has been directed to making the jig as nearly automatic as possible; and the result has been, in a number of instances, almost all that could be desired.

Attention has been chiefly directed to improving the arrangement for the discharge of the slate, with the result of a number of devices of more or less merit, but nearly all of which accomplish the desired result, which is to have the slate discharged as continuously and automatically as the washed coal, so that with the jig once started in operation, and regulated for a given quality of raw material and product, it will go on without interruption as long as material of the same sort is supplied to it.

One of these is that adopted in the Lührig jig, a machine which is meeting with much favor in the Zwickau, Saxony, coal field. In this machine the slate is discharged at the side of the sieve at the end of the jig, and, of course, as far forward as possible, through an opening carefully regulated as to height by a slide, into a closed narrow compartment in which a wheel is revolving, which is so constructed that it lifts the slate as it revolves and drops it outside of the compartment into a channel by which it is conveyed out of the building.

The lifting wheel is geared so that its revolutions correspond with the speed of the plunger, increasing its revolutions with the movements of the plunger, so as to deliver the slate as fast as it falls through the discharge.

Another device for effecting the same result, is the use of a small elevator for the removal of the slate from the side compartment into which it falls. This, too, can be regulated so that its speed shall vary with that of the plunger.

These are both successful in rendering the jig automatic by removing the slate without intervention of the attendant, and they are economical in the use of water; but the objection to them is, that they add unnecessary machinery to the jig, making it more complicated, increasing its expense and liability to get out of order. Moreover, the slate and pyrites are discharged only from one corner of the sieve, thus requiring the material from the opposite side to pursue a course either directly or diagonally across that of the coal, which goes directly down the sieve from the feeding hopper to the bridge. This tends, of course, to irregularity of action and uneven product; for there is danger that on the side farthest from the discharge, some slate may go over with the coal.

Another device to effect the discharge of the impurities is a short iron pipe, elliptical in section, open at both ends, and leaving a diaphragm or partition in the middle extending from one end to a height somewhat less than the height of the bridge or dam, but several inches less than the length of the pipe. At the end to which the partition extends, one side of the pipe is cut away to a height equivalent to the ordinary thickness of the layer of slate upon the sieve. The pipe is then bolted upright to the sieve frame, close to the bridge, but about the middle of the box; a hole is cut in the sieve the size of the half of the pipe which is resting upon it, and a connection made with another pipe to discharge below out of the box. The opening in the pipe allows the slate to enter, but not the coal, and by the pulsations of the water and the pressure of the column of coal and slate, it is carried over the low partition and out by the discharge pipe. The proper height of the partition and of the opening to receive the slate, must be determined for each particular case by the quality of the coal operated upon.

This discharge is shown in Figure 2, Plate II. It is very simple and efficient; it adds no machinery; being in the middle of the box, it does not offer so serious objections on account of the side motion of the material, as in the side discharge last described, although this is still one of the objections to it; and it is open at the top, so that the slate going over can be at any time examined, and any irregularity in the working corrected.

The chief objection to it is, that it requires a cutting of the sieve, which speedily results in its destruction; for any opening or defect is speedily enlarged by the shocks from the plunger. For this reason, this device is rarely applied to new machines; but it is a very cheap and successful one to apply to old jigs, which were not originally automatic in their discharge. This is its chief use; for new machines are generally made automatic through some other arrangement.

At the Mansuy Coke Works, near Neunkirchen, this discharge is applied to some old jigs, which were not originally constructed with automatic slate discharge. There are eight of these jigs in the establishment; but the director states that with three of them, furnished with the pipe discharge, he is able to do the same amount of work formerly done by the eight, thus showing that an automatic discharge more than doubles the efficiency of a jig.

The jigs for coal manufactured at the Humboldt Works, near Cologne, use a discharge upon the same principle, but it is set in the side of the box or frame, to avoid cutting the sieve, and the discharge of slate pours directly out of the box. The slides which regulate the flow are made adjustable, so that they will serve for coal of any quality. Two of these discharges are used, one at each of the front angles of the frame, thus reducing the objectionable side movement of the slate; for, to reach the discharge, it has to pass, at the greatest, only one half the width of the sieve.

All of these discharges are narrow, and of course do not give the regularity of work which a discharge the full width of the sieve would do.

All modern coal jigs, except those for fine or dust coal, discharge the washed coal over the bridge or dam, of the full width of the sieve, and it is almost as desirable that the slate discharge, to insure the best work, should be of equal width. By this means, there is no interruption to the natural motion of the whole material on the sieve; but it moves forward from the feed hopper, is gradually separated, and the coal and slate pass from the machine, in the same direction, through different openings, at their respective levels.

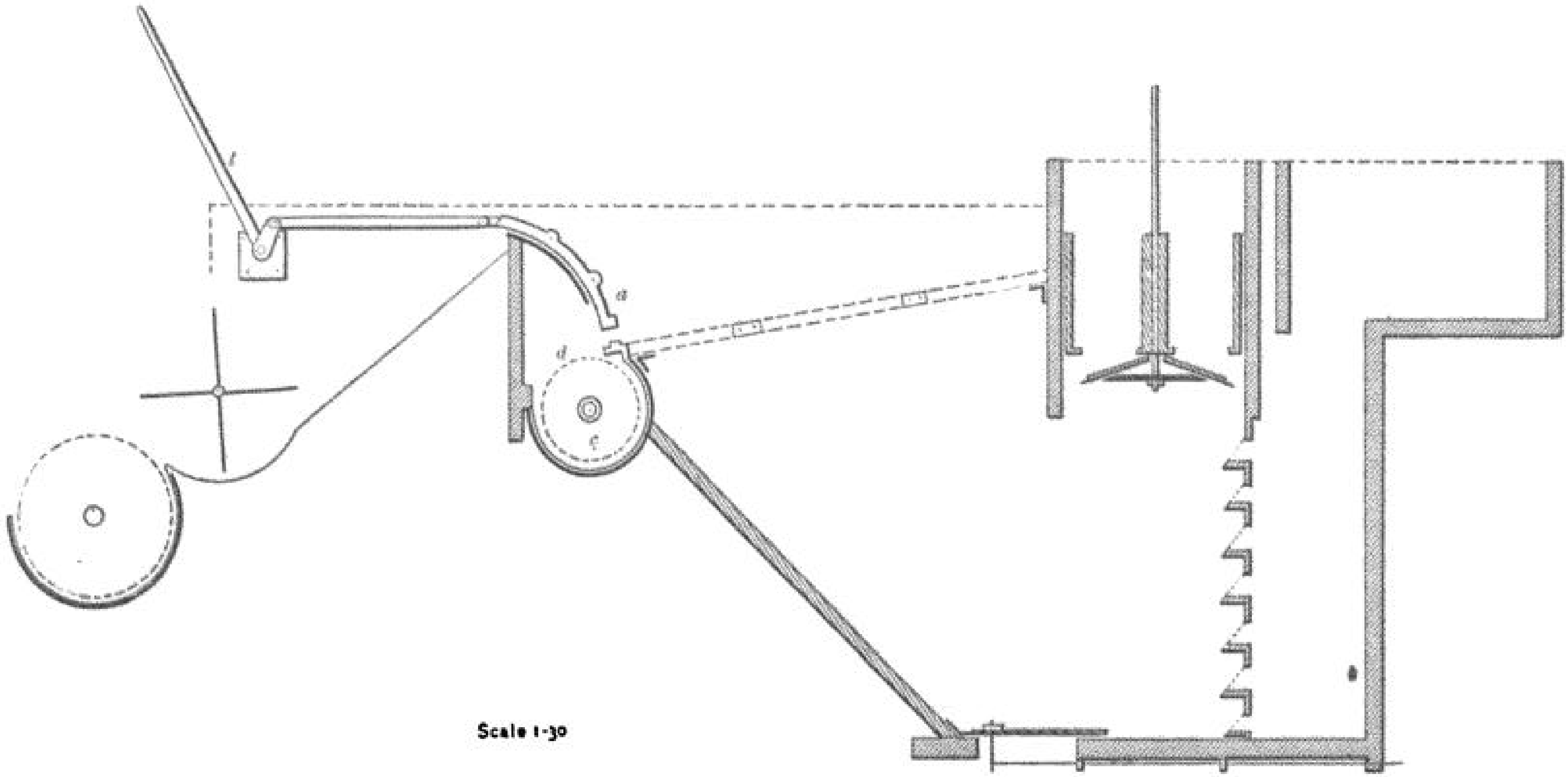
Where the amount of impurities is small, the narrow center and side discharges for the slate will serve; but with impure coals the advantages of a full width discharge are vastly increased. Several jigs have this feature, and among them two, worthy of description, are manufactured in Germany and used, one in the Saarbrücken coal field, in Rhenish Prussia, and the other in the Westphalian coal field. The first of these is known as the Rexroth jig, and is manufactured by the inventor at Saarbrücken, and used at a number of mines in the vicinity, where it is generally very highly recommended. The coal of this basin contains from 23 to 25 per cent. ash, and is reduced by washing to from 7 to 10 per cent. The principal impurity of the coal is slate.

A section, showing the Rexroth jig, is given in Plate III. It is a large wooden jig with plunger moved by simple crank, or eccentric. The peculiarity of the jig is the movable slide for regulating the outflow of the slate. This slide *a* is set at the proper position by the lever *l*. The slate passes through the opening thus made into the channel *c* and is carried out by the endless screw *d*. The washed coal passes over the bridge and down the drying screen to another channel and screw. A scraper is used to carry the coal from the lower part of the drying screen into the channel.

A jig with a sieve frame one meter (39.3 in.) wide, by 1.820 (71.6 in.) meter long, will wash, per hour, about three tons of coal, of the quality of that of the Saarbrücken field. This jig generally gives satisfaction; but at a coke works near Neunkirchen, the discharge apparatus had not proved efficient, for the pipe discharge had been added and was used entirely, the slide being kept closed except when it was desired to clean the sieve.

The second of the jigs above referred to is shown, in section, in Plate IV. It is known as the Kremer jig, and is manufactured by Messrs. Schüchtermann & Kremer, of Dortmund, Westphalia, and is coming into extensive use in the coal field of that name. It is an ordinary box jig, constructed of either wood or iron, and generally of large size, the sieve in the one shown being 1 meter (39.3 in.) wide, by 1.875 meter (73.6 in.) long, and the plunger being 1 meter by 0.750 meter (29.5 in.)

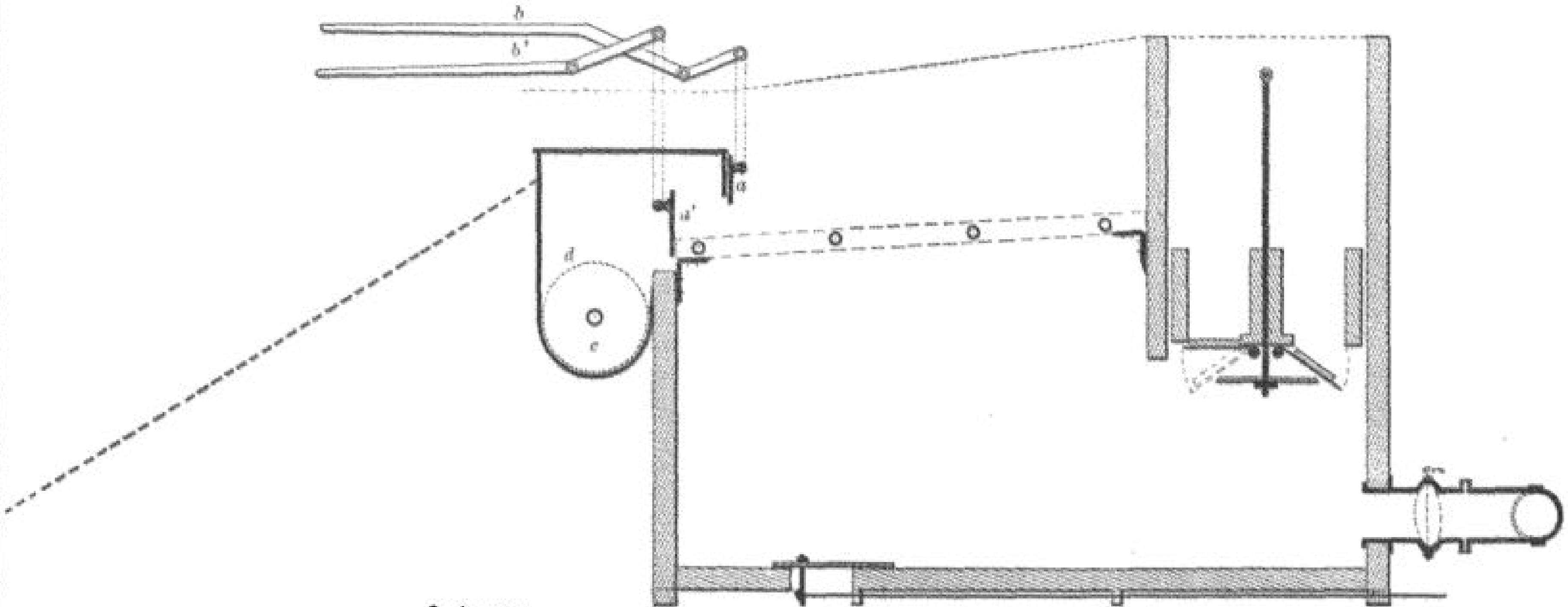
PLATE III



Scale 1-30

Rexroth Jig

PLATE IV



Scale 1-30

Kremer Jig

Treating Westphalian coal, which contains, as it comes from the mine, from 10 to 12 per cent. of ash, and is reduced in washing to from 3 to 6 per cent., a jig of the above size will wash, per hour, about five tons of coal.

The advantage of this jig lies in the excellence of the slate discharge; otherwise there is nothing remarkable about the machine. This discharge is an arrangement by which the principle of the pipe discharge, or the balancing of a higher column of less density by a lower column of greater density, is applied to the whole front of the jig. The manner in which this is done is clearly shown in the drawing. The two slide bars *a*, *a*', extending across the full width of the sieve, are made adjustable by means of the levers *b*, *b*', so that they can be moved to suit the character of the coal to be washed. The slide *a* is set so that the space between it and the sieve shall be just equal to the thickness of the layer of slate and pyrites which has been separated from the coal by the time it reaches the front of the sieve.

By this close adjustment, the slate passes forward under the slide, while the coal is lifted up and carried over the bridge by the lift of the water. The same force is able to throw the separated slate over the lower height of the slide bar *a*' into the channel *c*, from which it is carried out by the endless screw *d*, working in the bottom of the channel. The washed coal slides down the drying screen to another channel and screw, not shown in the drawing, as in the previously described machine. In practice, several jigs are placed side by side and made to discharge into a common channel, so that the washed coal and the slate of all the jigs are removed by two endless screws.

This jig is as nearly automatic as it is possible to make any such machinery. But one man is required to attend to the three or four jigs usually set side by side, and which are all the nut coal jigs in any ordinary establishment. After the slides are once arranged for coal of any given quality, and the proper frequency and height of stroke determined, the machine will wash and separate cleanly all the coal which is supplied to it, and, with a minimum of attention, will continue to do so as long as the quality of the coal remains constant. This machine is among the best for the treatment of coal. It combines efficiency with simplicity in a high degree, is meeting with great success, and is being introduced more than any other one pattern in the Westphalian coal field.

The above described jigs are only adapted to wash coal of size greater than from 4 millimeters (0.15 inch) to 6 m. m. (0.23 inch) diameter. Between this size and 40 m. m. (1.57 inch) they are capable of doing their best work, although in a few cases, as before stated, coal as large as 60 m. m. (2.3 inch) is treated in jigs. This is rare, however, as the impurities are generally so intermixed as to render it advisable to crush the coal finer before submitting it to the jigs, in order to secure a good separation.

It is usual to divide the coal between the limits above indicated into three or four different sizes, this having been found to be the economical limit of sizing. The extent to which sizing is carried, and the limits of each smaller subdivision, must be determined by the local circumstances at each colliery, the character of the coal, and the percentages of the different sizes which are produced by the mine without crushing. Coal can be, and is, successfully washed, with no separation between the limits of 4 m. m. (0.15 inch) and 25 m. m. (0.98 inch), and the experience of the managers of the Humboldt Machine Works, who have built many washing establishments, leads them to advise against close separation as being unnecessary. In this, however, their practice differs from that of most other manufacturers, who generally make the sizes above stated. In case of coals difficult of treatment, the sizing is sometimes carried farther than as above stated, and each size of coal is washed twice, and sometimes the larger sizes three times. This is the case at some of the collieries in Lower Silesia, where the coals have been very much broken and disturbed in situ, and contain from 20 to 30 per cent. ash.

The height and frequency of stroke vary for each size and are best determined by actual trial. With the larger sizes, the stroke is both longer and slower than is needed with the finer coal; but, as it would require an excessive amount of gearing to change the speed of each jig, it is common to give the three or four jigs usually coupled together an uniform speed, but a different stroke for each one. The speed for the jigs working the various sizes of nut coal is usually from 60 to 80 strokes per minute, and the length of the stroke varies from 30 m. m. (1.17 inch) in the finest to 150 m. m. (5.89 inch) in the coarsest sizes; this latter in exceptional cases, however.

The treatment of fine or dust coal, below 4 m. m. (0.15 inch), or 6 m. m. (0.23 inch) in size, is a matter of much more difficulty than in the case of the nut coal. It cannot be treated as other coal upon the ordinary jig, for the reason that, on account of its fineness and the fact that in it are often concentrated the most of the clay and other finely comminuted impurities, it clogs the sieves and passes through them instead of separating. Nor can the sieves be made close enough to prevent this, as they prevent, at the same time, the passage of the water through them.

In fact, so difficult is the separation of fine coal from its impurities, that at many collieries it is not attempted to wash it; but, after it is separated from the nut coal by screening, it is either thrown away, used for boiler firing, or some similar purpose, or, if it be not too full of ash, it is mixed, without washing, with the other coal after washing. The advisability of any one of these ways of disposing of the fine or slime coal must depend upon its impurity, and upon how much there is of it in proportion to the whole.

It sometimes, though rarely, happens that the dust does not contain as much ash as the nut coal; when this is the case, and it does not contain more than 10 per cent. ash, it is, perhaps, better to mix it with the washed nut coal than attempt to treat it by itself.

It has been found, however, that the fine coal can be jigged, with moderate success, by the use of a bed of broken feldspar or heavy spar, resting upon an ordinary coarse sieve. This use of a bed of material of greater specific gravity than the material to be separated has been long known in ore dressing, and it is applied to coal in exactly the same way.

The feldspar or heavy spar—better feldspar, however, as it gives a more regular fracture into angular pieces—is broken into pieces of a uniform size of 20 m. m. (0.78 inch), and laid to a depth of 40 to 60 m. m. (1.57 to 2.3 inches), upon an ordinary coarse sieve. The jig which is used for this purpose is shown, in both longitudinal and cross section, in Plate V. The coal is introduced at the end of the jig through the channel *a*, by which it is brought, in a stream of water, from a pointed box, which is used to approximately size the material. The coal moves rapidly along the upper sieve, passes over a low bridge to the lower sieve, and then out at the opposite end of the jig. The direction of the current is shown by the arrows in the drawing. The plunger is a solid one, moved by a simple eccentric, with a short stroke of 10 to 20 m. m. (0.39 to 0.78 inch), but making from 150 to 180 strokes per minute. The feldspar bed is, of course, kept open and loose by the movement of the plunger, so that the heavy impurities are gradually drawn through it, fall to the bottom of the box, and are discharged through the opening shown in the front. The coal, after leaving one, is sometimes made to pass through a second of these jigs, giving it a still better separation. It then flows by a channel to a series of settling tanks, where it is allowed to deposit, and the water is pumped back to be used over again. The discharged impurities are carried to a similar tank, there deposited, and subsequently removed.

The piston of this jig being tight and moving, with equal stroke, very rapidly, brings suction as well as gravity to separate the coal from its impurities, and to draw the latter through the bed. In consequence, the separation is an imperfect one, some of the impurities remaining with the coal, and considerable coal falling through with the slate.

It is considered, however, that the gain from the use of suction to draw the impurities through the bed, more than

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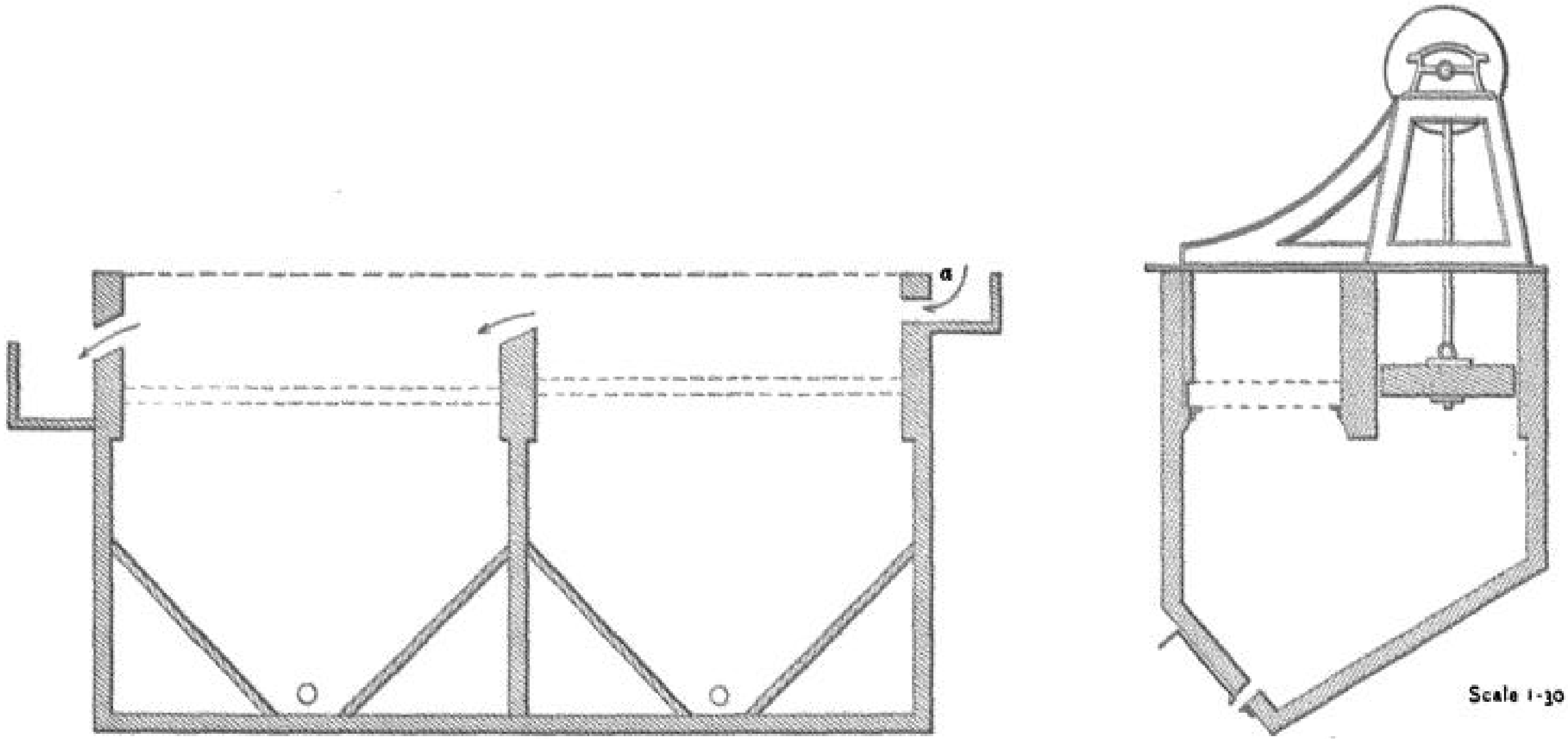
PLATE V



Jig for Fine Coal

R. D. Servoss N. Y.

compensates for its injury to a free separation. Moreover, necessarily using so rapid a stroke, it would be extremely difficult to make any appreciable difference in the length of the up and down strokes, and the shortness of the stroke prevents any relief by valves in the plunger.

The work of this jig is, at best, defective; but it is better than any other method of separation for fine coal as yet applied, and far better than no separation at all; and, where the fine coal forms a large proportion of the whole, it is almost necessary. It is not impossible that, eventually, it will be found best to treat the fine coal in some of the different forms of syphon washers, and thus do away with the difficulties of jigging.

Having described some of the jigs for separating coal from its impurities, before proceeding to a description of other forms of apparatus for the same purpose, but operating in a different manner, a little attention will be given to the auxiliary machinery for crushing, sizing, and transporting the coal and slate in the washing establishment, and for furnishing the necessary supply of water.

In most modern washing establishments, the coal is usually fed from the cars in which it is received to a pair of rolls, or a "coffee-mill crusher," in order to reduce it all to a size suitable for treatment in the jigs. This preliminary crushing is necessary, unless the screening at the shaft-house be done in a far more thorough manner than is usually the case. When the washing establishment receives coal from a number of mines, a crusher is essential to secure uniformity. The object of this crushing is to reduce the coal to as nearly uniform size as possible, and with the least grinding or pulverizing, to break the coal into cubical fragments. To this end, therefore, a cutting or splitting action of the machine is desirable, rather than a crushing, which increases the amount of fine coal. The "coffee-mill' crusher is generally preferred where the coal is moderately soft and does not contain large, or numerous lumps of pyrites, which are likely to injure it seriously. This mill breaks the coal into better shaped fragments than the rolls, and its work is chiefly done upon the larger pieces, the finer coal working through, for the most part, without much further breaking. Thus the amount of waste, in the shape of dust, is not largely increased.

With the rolls, on the other hand, all that passes between them is more or less broken. The mill has further advantages where the coal, as in much of that from the western coal field, possesses a very easy fracture along the planes of the bedding or stratification, which tends to split it into long, flat slivers. This is a decided objection; for, the more nearly uniform are the pieces in all their dimensions, the better will be the separation, and the thin, flat pieces of slate are easily lifted and carried over with the specifically lighter coal.

Where rolls are used, the faces are generally grooved at right angles to each other, so as to counteract the natural cleavage as much as possible, by cutting the coal into cubical fragments. This grooving is sometimes diagonally around each roll, so that the grooves cross each other at right angles, as the rolls turn, or it is parallel to the axis in one and perpendicular to it in the other. The rolls are usually provided with heavy rubber springs, which yield in case any substance of unusual size or hardness falls between the rolls, and thus prevent any accident.

From the preliminary crusher the coal is usually carried by an elevator to the top of the building, where it is fed to the screening drum. These screens, which separate the coal into its different sizes, are conical or cylindrical drums, revolving on a horizontal axis, and formed of perforated iron or steel plates, or of wire netting. The latter is used where there is much clay, which tends to clog the holes in the plates, especially if they be of the smaller sizes. The perforated plates are preferred in other cases, as they wear very much longer. The conical form is also almost always preferred, as, with a horizontal axis, the conical drums empty themselves by gravity, being fed, of course, at the small and discharging at the large end. They are made of a great variety of forms, sometimes double, where it is necessary to economize space, the outer sieve in this case being the fine one, and serving to separate the dust at once. The screening is done both wet and dry, depending upon the character of the coal. Where possible, it is best to use water, as it prevents dust. The water is applied in fine jets upon the outside of the drum, thus washing back from the holes any obstructions that may have accumulated in them.

Where there is no sizing of the coal before it goes to the jigs, a short drum with dust mantle is enough. The coal is fed into it from the hopper, into which it is thrown by the elevator, the lumps (above 25 m. m. (0.98 inch), or 40 m. m. (1.5 inch), as the case may be) too large for the jigs fail to pass either screen and fall out at the end, whence they go back to the crusher, or are hand-picked on a revolving table and sold; the dust passes both sieves and is carried in a stream of water to the pointed boxes, where it is classified for the fine coal jigs, while the nut coal passes through the first sieve and out at the end, whence it is carried by a revolving screw, or some similar device, to the hoppers above the jigs.

Where a more complete sizing is desired—as, for instance, where four sizes are made above the dust coal—a second longer drum, but of smaller diameter, is placed a little below the first, so that the nut coal will fall into it. This drum is formed of perforated plates of three different sized openings, each size forming a third of the drum, the finest openings nearest the receiving end. This gives three sizes, and the fourth and largest is formed by that which passes out at the end of the drum. The screening in this drum is almost always done wet, much more uniformly so than that with the first drum. When the screening with the first drum is done dry, it is all carefully covered, so as to confine the dust as much as possible. The second sizing drum is usually placed immediately above the nut coal jigs, so that each size falls from the screen to its proper jig. The determination of the proper sizes to be given is best made after careful examination of the coal; for it is desirable to adapt the sizing and the percentage of space given to each class, to that which the coal naturally assumes on being crushed. This must be done in order to secure a uniform supply to each jig, as otherwise one jig would have more than it could wash, and another would be insufficiently supplied. There can be no general rule given which will answer for every case. The practice must depend upon the cleavage of the coal. Coal will break on crushing into very different proportions of the various sizes. It is a matter of easy determination by experiment, however. A careful screening through sieves of different sizes, of a small known quantity of coal, and the weighing of the different screenings obtained, will quickly determine the proper percentages.

There is no attempt to carry the sizing of the dust coal by screens any further; it is only classified by settling in water in pointed boxes. This classification is due to the different rate at which particles of different sizes will fall in water. There are usually three of these boxes in a set, each of which feeds a fine coal jig of the pattern already described. The fine coal is conducted in a stream of water to the first of these boxes, which it fills and then overflows into the second and third. The coarsest of the coal is deposited upon the checking of the current in the first box, the medium in the second, while the finest is carried to the third and beyond. This separation is a rude one, but it is the best which has yet been accomplished on a large scale.

From the bottom of each of the boxes a channel leads to one of the fine coal jigs, and through it the material which has settled flows to them. The size of the openings which discharge from the bottoms of the boxes is not sufficient to allow all of the water to pass, and there is, therefore, an overflow from the third box. This overflow is, sometimes, carried to a jig, but more often led directly to the settling reservoirs. It contains but little coal, the most of it having settled in the boxes; but that which it does contain is very fine and quite free from impurities.

All of the water from the screening drums, and also that from the jigs, which falls through the drying sieve after discharging the washed coal, is led to these pointed boxes to deposit as much as possible of the coal held in suspension, which is a considerable quantity, due to the grinding of the pieces of coal against one another during the violent movements in the jig.

At a colliery near Waldenburg, in Lower Silesia, instead of the pointed boxes, a single large tank or box is used. All that settles to the bottom of this box is carried by a stream of water to the fine coal jigs, while the finer, lighter material is discharged through an opening, at a higher level, directly to the settling reservoirs.

From the fine coal jigs and the boxes, the water containing the washed coal is led to settling reservoirs, which are usually long rectangular masonry chambers, ranged side by side, four or six together, with inlets and outlets so arranged that the water can be turned into any one of them, or from one to another, while the others can be shut off. In these, the water comes so nearly to a rest that the most of the coal it holds is deposited, and the water is pumped back by the centrifugal pump, with which the works are usually furnished, to be used over again.

In Europe, where the country is thickly settled, the disposal of the fine slate and impure coal discharged from the bottom of the fine coal jigs is a matter of some trouble, as it is not permitted to be turned into the streams on account of the pollution of the water. It is, therefore, allowed to settle in reservoirs, as with the coal, and then removed by wagons. With us, for the present, at least, there will be few places where such a small amount of impure water flowing into the streams will be productive of any damage; and this, the simplest method of disposal, can probably be adopted in almost all cases.

Where water is easily obtained in ample quantity, the sur plus dirty water from the fine coal settling reservoirs will also probably be allowed to flow off, and a constant supply of clean water will be used. The use of water over and over again is entirely practicable; and where there is a scarcity of clean water, or where it is not permitted to allow the dirty water to flow off into the streams, it is advisable; but otherwise not, as much better work can be done with clean water. There is always some waste, which must be supplied with fresh, even when the greatest care is exercised in saving the dirty water. The fine coal or slime, which is deposited in the settling reservoirs, is an objectionable product, in that it is difficult to handle, and, except in very fat coals, will not coke well unless it is mixed with the other washed coals. It is, therefore, desirable to produce as little of it as possible, where this can be done without wasting coal. To this end, a plan is in successful operation at the coke works of the Wigan Coal and Iron Company, Wigan, England, whereby the water containing the slimes or fine coal is not allowed to settle as it comes from the works, but is kept agitated by a stirrer until it is pumped back to the jigs. By this means no fine coal at all is deposited in the tanks; but it is all mixed with the nut coal in the jigs and remains with it; nor is it found that the percentage of ash is materially increased thereby. This is due, of course, to the character of the fine coal at this place; at another, it might not be practicable, as the fine coal might contain a larger percentage of ash than any other size.

Where the coal is a good coking coal, and is all used for coking, it is generally, after washing, all reduced to a very fine powder by means of a centrifugal disintegrater. This is done for the production of a more homogeneous coke. Where the disintegrater is used, the endless screw, which removes the washed nut coal from the jigs, discharges into the hopper which feeds the machine. The pulverized coal is carried by an elevator to the top of a tower especially erected to hold it. From this it is discharged as it is wanted, into the wagons which carry it to the coke ovens.

The fine coal from the settling reservoirs is generally carried by another elevator to a similar tower. The elevators and transport screws, which are used for moving the coal from place to place, are too well known to need any especial description.

In Europe, where so much of the dirty water is used over again, centrifugal pumps are in most common use, as they are considered best adapted for such service. In this country, especially if using nothing but clean water, piston pumps are preferred.

The amount of water needed is large, varying, of course, with the thoroughness of the washing and the original impurity of the coal. If the supply of water be scanty, a large part of it can be saved in the settling reservoirs and used over again, but there is always some waste which must be supplied from the original source. Clean water, of course, gives the best results, and is to be preferred if it can be used entirely. The amount used varies in different establishments, with different jigs, with the number of times the coal is washed and with the washing of the fine coal; where the pure coal is not washed and the screening is done dry, the consumption of water is hardly more than one half of what it is otherwise; for although the fine coal is not often more than 20 per cent. of the whole, it requires a very large amount of water to separate it.

On account of the above mentioned differences, it is difficult to give a general statement of the amount of water used, but the total consumption for all purposes varies from 300 to 600 cubic feet per ton of 2240 pounds.

The cost of washing is also as difficult to state, in general terms, for it must vary so with the circumstances of each locality. Where the coals are very impure and require to be washed twice to thoroughly clean them from their impurities, and where, in consequence, the waste is large, the cost is, of course, far more than under ordinary circumstances.

The average cost, as obtained at a number of establishments in the different coal fields of Germany, is 55 pfennigs (about 14 cents) per ton of 2204 pounds of coal washed. There, however, with the exception of the Westphalian coal, the coals contain from 15 to 25 per cent. ash, which is much more than the average of our Western coals, and double in many cases. Labor is there much cheaper, but more of it is employed for the same amount of work.

The coals of Kentucky, both in the Eastern and Western fields, present no serious obstacles to successful washing; on the contrary, their impurities can be removed with ease and with little loss. The chief impurity is sulphur in the form of pyrites, which, except when it occurs in fine flakes or scales upon the coal, is very easily separated, as its specific gravity is nearly four times that of the coal. The ash is rarely more than from 10 to 15 per cent., and generally under the smaller figure, while often it will not be more than 7 or 8 per cent. in a coal which carries 2 or 3 per cent. of sulphur. It is probable that some of the sulphur is present in organic combination and not in the form of pyrites. Unfortunately, the necessary analyses have not been made to determine this; but from the above noted fact, and from the determinations made in the Ohio coals by Prof. Wormley, of the Ohio Geological Survey, by whom the discovery of this combination was first made, there is reason to believe that it is the case. If it be, the sulphur will not be removed by washing, but will be expelled in coking. There is evidence enough, however, visible to the eye, that the greater portion of it is in the form of pyrites. In some of the coals of the Western field, there may be a little trouble from the clay which has been washed in between the seams, but these will be confined to a few localities. For these reasons, therefore, the loss in washing will not be great, and only one washing will be necessary. It is not probable, therefore, considering the ease with which the separation can be effected, that the cost will exceed that above stated, and it may be brought materially below.

If the coal to be treated is a waste product, not very impure, and there is an abundance of water, a separation can be effected by the trough washer even more cheaply. In fact, it is to be recommended as a trial washer in many cases.

There is no doubt that, by the use of the proper apparatus, the coals of Kentucky can be easily and cheaply purified, and much that is now a waste product will become a source of profit, with the eventual result of a wider market, better

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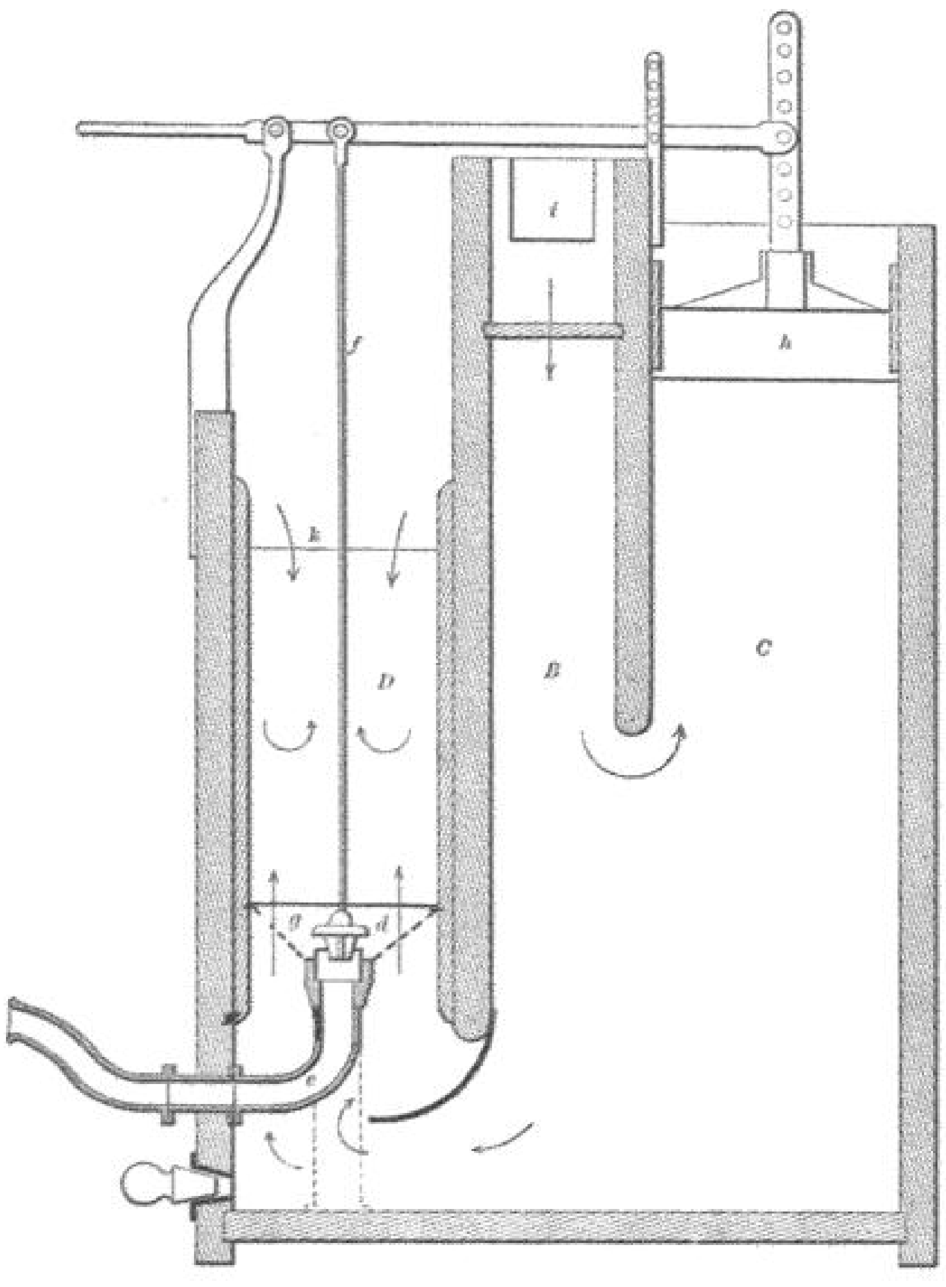
PLATE VI



Scale 1-30

Osterspey Syphon Washer

R. D Servoss N.Y.

demand, and a great increase in the development of the industrial resources of the State.

CLASS III. SYPHON WASHERS.

This class of machines has not, as yet, to the knowledge of the writer, passed beyond the experimental stage in coal washing; but they possess advantages for the treatment of fine or dust coal, which will not improbably bring them into use in place of the somewhat unsatisfactory fine coal jigs.

In Plate VI is shown one of the most recent of the syphon washers. It is known as the Osterspey syphon washer, and is patented in the United States by Adolphus Meier & Co., of St. Louis, Missouri. It consists of the three chambers *B*, *C*, *D*, of which *D* is the separation chamber. The water flows into the apparatus through the channel *i*, down through *B*, and up through *C* and *D*. The material to be separated is carried through an inclined trough, in a stream of water, and delivered at the level *k*. It meets here the ascending current, and the lighter portions are carried out at the same level *k*, but on the opposite side of the box. The heavier material falls through the current of water to the sieve *d*. It accumulates here until it checks the flow of water, and by the back pressure raises the level of the water in the chamber *C*. This raises the float *h*, which is connected by a lever with the valve rod *f* and the valve *g*, and opens the valve, when the material upon the sieve is discharged through the pipe *e*. With the discharge of the material from the sieve, the obstruction to the flow of water is removed, the water in *C* falls, the float *h* follows and closes the valve, which remains closed until a sufficient amount of material has collected upon the sieve to check the current and repeat the operation above described. The machine is, therefore, automatic in its operation; and, so long as the head of water is constant, will discharge the material as fast as it separates. In practice, three of these machines are placed side by side, the overflow from one passing into the next, where it is again treated in the same way. Operations have not been conducted with it upon a sufficient scale to enable exact statements of its efficiency to be made; but the experiments with it by Messrs. J. W. & E. D. Meier, of St. Louis, Missouri, have been so satisfactory that it will be used at the coal washing establishment of Messrs. Adolphus Meier & Co., in East St. Louis, for the treatment of the fine coal.

Mr. B. F. Day, of Tamaqua, Pennsylvania, has invented a machine, upon a similar principle, in which the water is introduced from the sides of the separation chamber, and forced upward by two small propellers, which revolve in opposite directions. The material to be separated falls from a hopper, and meets the upward current of water. The lighter particles are carried over the sides of the chamber, while the heavier fall through the stream into the quiet water at the bottom of the chamber, below the level where the water is introduced, and are discharged, from time to time, by opening a valve. This machine has the advantage of being exceedingly simple; but its efficiency is entirely dependent upon the uniformity of the speed of the propellers. Any variation in this, results in a derangement of its working and a change in the character of the product, as the current of water must preserve an uniform velocity to secure regularity in the separation. It has not, as yet, been introduced in actual practice in coal washing.

CLASS IV. THE EVRARD COAL WASHER.

This machine is in use in the vicinity of St. Etienne, France, where it is claimed that it does its work very thoroughly and cheaply.

Its peculiarities are, that it works a very large quantity in a thick layer at one time—as great as one meter (39.3 inch) thick—and that it requires no sizing at all, the slack coal being submitted to it as it comes from the screens at the shaft house, dust and all.

It is shown in Plate VII. This drawing, and the following description, are copied from the Metallurgical Review, volume 1, number 5, January, 1878:

"The washer is composed of two vertical vessels, either

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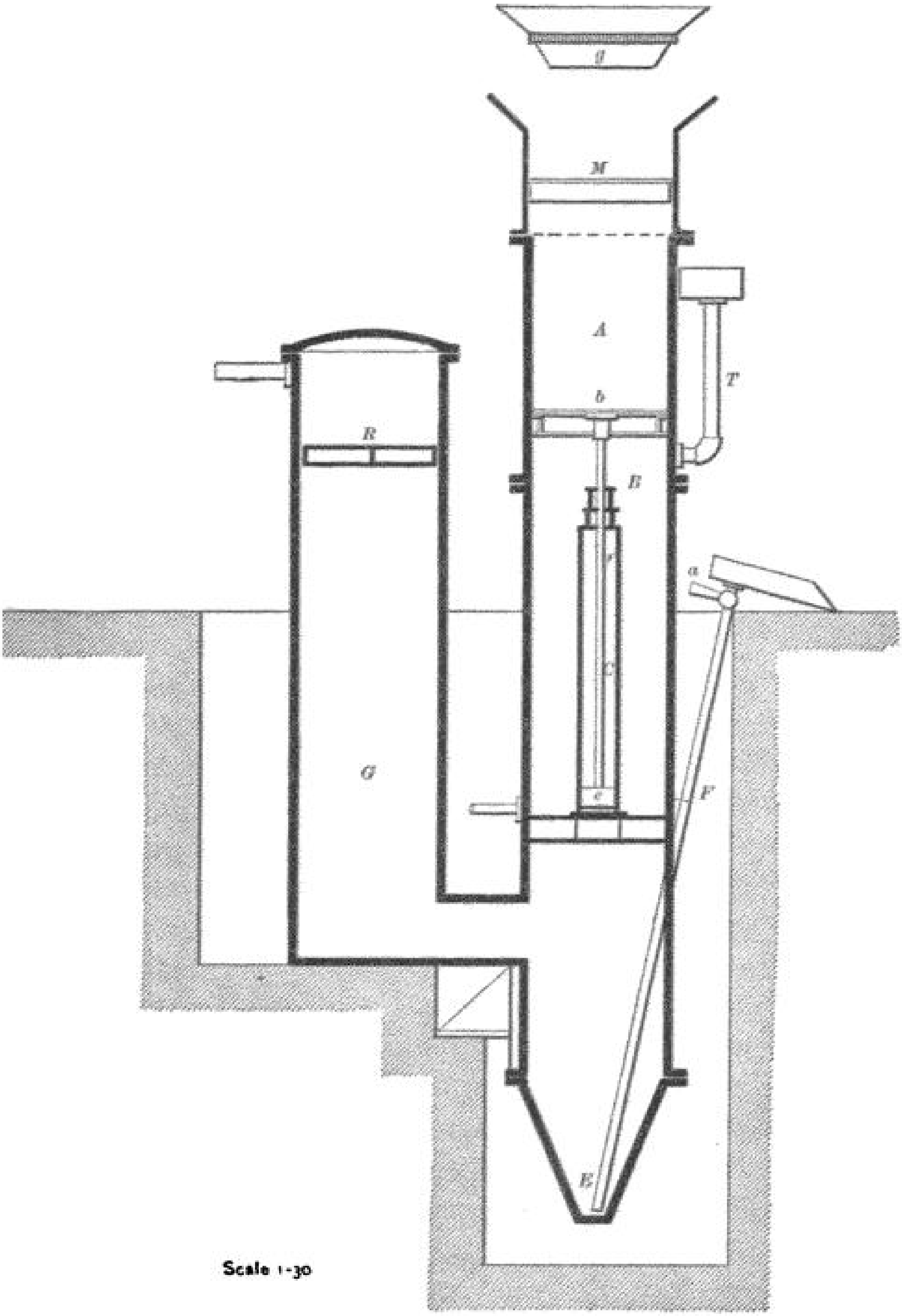

Scale 1-30

Evrard Coal Washer

R. D. Servoss N. Y.

cylindrical or of any other form, in communication with each other. The vessel which receives the material is provided with a washing table supporting a screen or sieve. This table fits closely, and may remain motionless, or rise and fall the entire height of the receiver. Both vessels are partly filled with water, and steam is introduced into one vessel to act on a float which divides the water from the stream. The material is emptied into the vessel *A* upon the screen *b*, having previously passed through a grating *g*, in order to remove the lumps. Care is taken to maintain the water level about 18 inches above the table *B*, so that the fine particles shall not pass through the screen. After the charging is completed, the water level is raised—by the admission of steam into the vessel *G* above the float *R*—in order to bring the dust and dirt to the top of the charge. The steam is then allowed to escape from the receiver; and if the dust and dirt, which frequently form an impermeable layer, do not permit the water to return into the vessel *G* (being retained by a vacuum below the washing table *B*), a cock of the pipe *T* is opened to let air in, and fill the free space left by the displacement of the volume of water.

"Thus the column of the latter is divided, part of it being above the charge. By a new admission of steam into the vessel *G*, the air below the washing table is forcibly driven through the entire charge, producing a species of ebullition which facilitates separation. The water which follows the air through the table rises in the vessel, and, by an intermittent current, the desired result is obtained. The impurities of fine slate and sulphur contained in the upper layer will descend into the lower layers after a few liftings or aerations, and the upper layer should then be removed in order to continue more easily the separation of the remaining layers.

"The washing table is next lifted by the piston *c* and rod *r*, so as to bring the upper portion of the cleaned coal level with the orifice of the vessel, that it may be discharged. From this time the separation of the mass continues without inconvenience—the impermeable layer having been removed.

"The oscillations are repeated by the admission or escape of the steam into the vessel *G*, and thereby the densest grains or particles are brought into the lower layers. As the separation progresses, the table is raised and the layers are removed. The layer immediately above the stones, and the stones themselves, should only be removed after several operations, and then only in part. This is necessary in treating charges of different sizes, in order to establish best the line between the several layers of large pieces which occupy the lower parts. Water is supplied, when the water level is at its lowest, by a channel opening into a reservoir at a higher level. To remove the clean coal from the preparatory washing vessel *A*, a scraper *M*, sliding in guides and worked by a winch, by steam or hydraulic power, is made use of. The fine sediment which settles down into the sump *E* is let out through the pipe *F* by opening the cock *a*."

The apparent objections to this machine are, that it is complicated and irregular in its operation, and that it requires too much attention. The writer does not speak from personal observation, however, and has had access to few details of its operation.