Please read and send in as full a discussion as possible at earliest date.

The Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF—(*Subject to revision*).

COAL WASHING AS PRACTISED BY THE NOVA SCOTIA STEEL AND COAL COMPANY, AT SYDNEY MINES, CAPE BRETON, N. S.

By C. L. Cantley, Stud. Can. Soc. C. E.

(To be read before Mining Section, April 2nd, 1908.)

The cleansing of coal to fit it for metallurgical purposes is a branch of the art and science of ore dressing which has become prominent only at a comparatively recent date in America. The reasons for this are quickly brought to mind when we remember the growing scarcity of pure fuel and the refinements of metallurgical methods which now make fuel treatment necessary, except where Nature has been especially kind to the metallurgist.

In Canada, the greater part of our fuel is not sufficiently pure for the economical smelting of iron, and hence it was that one of the first coal washers to be built and operated in America was laid down in 1892 at Ferrona, Nova Scotia, by the New Glasgow Iron, Coal & Railway Company, at that date a constituent of a company which afterwards became the title company.

The success obtained on the product of the neighbouring mines induced Mr. Graham Fraser, at that time managing director of the Nova Scotia Steel & Forge Co., to carry out a series of experiments in and about the year 1894 on other Nova Scotia coals, and especially to test the coals of Eastern Cape Breton with a view of seeing whether a good enough coke could be made to warrant the establishment of an iron and steel industry on that island.

The experiments proved conclusively that by this method of treatment coals containing a high percentage of ash and sulphur could be so prepared as to make a coke of good quality, at a treatment cost not exceeding ten cents per ton, and to these successful tests we owe the establishment of the iron and steel industry of Cape Breton.

Thus we see, from the outset, the fundamental importance of this branch of dressing which has made possible one of the greatest industries in Eastern Canada; this is further emphasized by the recent troubles in Canadian steel-coal circles brought about by coal being supplied which, it was claimed, could not be sufficiently purified by washing to make good metallurgical coke.

The Nova Scotia Steel & Coal Co. in 1896 purchased the entire property of the General Mining Association of London, which operated the well-known "Old Sydney" main seam at Sydney Mines, Cape Breton. The intention then was to utilize part of the coal mined for the manufacture of coke to be used in iron blast furnaces, and in 1899 the plant described in this paper was laid down at the colliery, the general scheme being similar to that of the plant previously erected at Ferrona. As originally designed, by Stein & Boericke, metallurgical engineers of Philadelphia, and erected, the plant was expected to handle 300 tons of coal per day of ten hours. It has, however, been much altered in details, chiefly of elevators and waste disposal, so as to have a uniform washing capacity throughout, and, as a consequence, the output is now over 500 tons per day.

The plant is situated in the immediate vicinity of the colliery, from which it formerly drew all its coals. Now, however, the coals treated are screenings collected in cars from several collieries, and are what is locally known as culm or duff, that is to say, the screenings removed from the run of mine coal as prepared for the market. These screenings include practically all the fire-clay contained in the clay parting between the coal seam and the roof and the foot wall. The undercutting being in the clay-band next the foot wall, the proportion of ash in these screenings is from two to three times as great as in the seam coal proper.

An outline of the whole process is shown in the appended sketch.

The cars of screenings are emptied, as required, into No. 1 elevator pit, and the coal is lifted by bucket elevator to a Robins belt conveyor, which carries it 135 ft., over sidings, to the breaker house, where it is lowered by chute to a modified type of Jeffry rolls. These rolls are 24 inches in diameter, and turn at 180 and 270 revolutions, respectively, per minute in opposite directions.

The original rolls (the frame being of cast iron) were designed with one roll stationary and the other adjustable, the adjustable roll being held within a half-inch of the other by means of a counter weight acting through a toggle joint applied to each bearing of the moveable roll, it being necessary to have one adjustable on account of foreign material, such as bolts, spikes, etc., finding their way into them with the coal.

While the toggle joints gave very good results for small pieces of iron and rock, they would not allow the rolls to open up quickly enough to pass a two-inch machine pick, and this caused frequent breakages of the roll frame. To overcome this trouble the cast iron frame was discarded and the original rolls, bearings, and toggle joints were mounted in a frame consisting of two steel channel irons on each side, with a top and bottom cover plate, forming a box girder; to this girder is fastened, on each end, cast steel pedestals to receive the bearings, these last being held to the girder by means of four ¾-inch machine bolts. The effect of this construction is that when a machine pick passes through the rolls, and the toggle joint does not act quickly enough, the four ¾-inch bolts, holding the pedestals to the girder frame, are sheared off, allowing the rolls to separate and causing no other damage than the loss of the four bolts, which are easily replaced, and the machine put in running order again.

The product is elevated by No. 2 elevator and deposited on a shaking screen with ½-inch perforations. The screenings fall directly to No. 3 elevator pit; all portions larger than ½-inch going over the screen into plain rolls, 16 inches in diameter, and running at 80 revolutions per minute, and thence to No. 3 elevator pit. From here all the coal of ½-inch diameter and under is elevated by No. 3 elevator to the raw coal storage tank, which is built of steel, brick lined. This storage tank is self-trimming, and holds 1000 tons, a feature which permits a supply of crushed coal to be kept one day ahead. Thus the washer proper is enabled to run on a day when the colleries are idle. The bottom of the tank is designed with two rows of parallel openings, fitted with sliding covers, each in line with a horizontal scraper conveyor delivering the crushed coal to the foot of No. 4 elevator, which delivers it in turn upon the shaking screen. This last has ⅜-inch perforations, and being set at an angle of about 15 degrees, is supported upon rocker arms, and has an eccentric motion closely resembling that of hand screening. Owing, however, to the fine coal being more or less damp, it is impossible to separate the two sizes on a dry screen, so that, as the coal is delivered to the screen, it is met with a number of jets of water, which flush the coal through the screen plates. When the screen was flushed with the ordinary coal washing water the perforations in the jet pipes became plugged up, consequently clear water has to be used, and a cheap and convenient supply is found in the circulating water from a surface condenser, connected to the main centrifugal pump engine; this water being warm is less trying for the jig tenders, who have their hands immersed continually. The combined effect then of the incline and the supply of water is to rapidly flush away by flume those screenings under $\frac{3}{8}$-inch to the fine jigs. The remainder, under $\frac{1}{2}$-inch and greater than $\frac{3}{8}$-inch, being sluiced to the coarse jigs.

There are four coarse jigs on one side of the building, and as many fine ones on the other, all of them being essentially modifications of the Lührig jig, and designed especially for coal washing work by Mr. Stein, the engineer whose firm had charge of the erection of the plant. The fine jigs, styled "Standard two-compartment fine corn jig" by the designer, are built of wood, and wash $7\frac{1}{2}$ tons of coal per hour.

Thus about 65 per cent. of the coal is washed by the fine jigs, since only three of the coarse jigs, with a capacity of six tons per hour each, are used at a time. The fine jigs, which have one compartment fitted with $\frac{1}{4}$-inch perforated plates, and the other with $\frac{3}{8}$-inch perforated plates, are run at 135 pulsations per minute. The feldspar used in the bed is of $\frac{5}{8}$-inch cubes. The coarse jigs are run at 72 pulsations per minute, and have a bed of $\frac{7}{8}$-inch feldspar varying from 2″ to 4″ in thickness, depending on the amount of slate flowing. The purified product from the jigs is sluiced to the washed coal bin, while the slate runs to a waste bin, from which it is removed by No. 7 elevator to the slate bin in a Bernard storage tower, or flushed away by the slate ejector.

The water from both these bins, carrying in suspension certain fine coal and extremely fine particles of slate, returns to the sludge tank, directly under the jigs. There this fine material settles, and at proper intervals is drawn off. This tank, being the reservoir to which all leakages drain, also acts as a sump for the washer, and the centrifugal circulating pump drawing from it uses the water over and over again. Thus the only loss of water is that carried away by the products as moisture, a small amount as leakage, and that used for flushing purposes. This amounts, in all, to about 25 per cent. by weight of the coal washed.

The washed coal is all elevated to a drainage and storage tower by No. 6 elevator, which is equipped with perforated buckets, as also are elevators Nos. 5 and 7, and the amount required for the coke ovens is lowered by chute and re-elevated by No. 5 elevator to another tower. This additional handling is found to pay, owing to the reduction of moisture by drainage.

The amount of water required in circulation is about 2000 gallons per minute, and is supplied by a 12-inch centrifugal pump direct connected to a 12 x 10 vertical engine, running at 250 revolutions per minute. This engine exhausts into a surface condenser, the circulating water of the condenser being used as mentioned above to flush down the coal over the shaking screen.

As originally laid down, a 100 H. P. engine supplied all the power necessary, but now electricity is used for motive power as follows: Crushing house complete, including elevators; one Westinghouse 75-H. P., 60-cycle, 3-phase, 200-volt, 650 revolutions per minute, induction motor; washer house proper, jigs, etc.; 50-H. P. induction motor of the same type; Bernard tower; 30-H. P. 220-volt induction motor.

The following analyses are in each case averages of many determinations, and represent as close an approximation to the actual composition of the products as can possibly be obtained. The raw coals from the separate collieries have been analyzed at regular intervals over a period of several consecutive months and give the following results.

Coll.	Moist.	Vol. and Comb. Mat.	Fix. Carb.	Ash.	Sulphur.
A	4.86	29.11	56.73	14.87	2.14
B	5.96	28.38	57.38	14.23	2.09
C	6.51	23.11	54.27	22.61	2.45
Aver.	5.77	26.87	56.12	17.23	2.23

As the weight of coal received from each colliery for each month was known, the following analyses of the mixture received at the wash plant for each month were calculated, and are as follows:

ANALYSIS OF COAL MIXTURE DELIVERED AT THE WASH PLANT.

Month.	Moist.	Vol. and Comb. Mat.	Fix. Carb.	Ash.	Sulphur.
1	5.62	27.71	56.48	15.93	2.17
2	5.61	27.82	56.50	16.08	2.18
3	5.67	27.75	56.54	15.83	2.16
4	5.69	27.40	56.31	16.43	2.19
5	5.68	27.25	56.28	16.72	2.20
Aver.	5.65	27.56	56.43	16.19	2.18

The average analyses of the washed coal resulting from the washing of the above coal, and covering the same period, are as follows:

Month.	Moist.	Vol. and Comb. Mat.	Fix. Carb.	Ash.	Sulphur.
1	17.25	34.86	60.58	4.52	1.27
2	13.87	35.51	62.00	3.96	1.25
3	10.95	38.20	66.14	3.64	1.45
4	14.01	28.70	65.56	5.80	1.84
5	11.00	37.92	57.36	4.72	1.75
Aver.	13.42	34.94	61.71	4.33	1.51

Thus it is seen that the average reduction for the five months has been from 16.19 per cent. to 4.33 per cent. in ash, or 73 per cent., and in sulphur from 2.18 per cent. to 1.51 per cent., over 30 per cent. reduction. It might be said in regard to the above figures that the greater quantity of ash in the coal in the last two months was due to the increased percentage of "C." coal used. This coal was not run over a picking belt since that colliery was newly opened, and was not as well equipped as the other collieries.

The most prominent feature of the coal treated, a soft bituminous variety, is the high percentage of volatile and combustible matter which is typical of the Cape Breton coal measures. The coal also has a high percentage of sulphur and more ash than is consistent with economy. Most of the impurity is present in the form of slate, there being only a small percentage of bone coal. The following analysis is that of the impurity which sinks in a calcium chloride solution of 1.35 specific gravity:

$Fe\ S_2$	13.64	
$Si\ O_2$	28.50	combined
Al_2O_3	17.59	as slate.
$Ca\ O$	6.74	
$Mn\ Co_3$	2.91	
$Mg\ O$	0.44	
Chem. Comb. H_2O	15.10	
Carbonaceous matter	14.80	mostly bone coal.
	99.72	

The sulphur contained exists for the greater part as iron pyrites ($Fe\ S_2$), which seems to occur evenly and uniformly distributed through the coal and bone in the form of small nodules, leafy formations between the layers, and as a series of particles in size between 80 and 100 mesh; moreover, some of the sulphur is present as organic sulphur. It is impossible to get rid of this latter portion by any specific gravity method of separation, and it is called the fixed sulphur.

The following are the specific gravities of the coal constituents:

Slate...	3.83
Coal...	1.27
Splint or bone...	1.50
Pyrite...	4.80

In order to determine the best possible separation that can be effected with the coal in question by means of a specific gravity method, the following experiment has been made: A calcium chloride solution of slightly higher specific gravity than that of coal, and less than that of the other constituents, was put into a glass jar of about ½-gallon capacity; to this solution was added a weighed quantity of coal of the same size as supplied to the jigs. The contents were stirred briskly and allowed to settle. The sample was now found to be divided into two portions. All particles of a specific gravity less than that of the solution had floated, while all the particles heavier than that had gone to the bottom. Between these two layers there remained suspended in solution a small proportion of the particles whose specific gravity was about that of the solution. The floating and sinking portions were separately removed, washed free from the solution, weighed, and analyzed. From the data thus obtained we calculate the purity and yield of the floating portion or the washed coal obtainable. This is the simplest and most effective coal washing operation that can be performed, and the results of this experiment determine absolutely for any coal the maximum purity of the washed coal obtainable from it by any washing process. The calcium chloride solution used was of 1.35 specific gravity, which was found best suited for this coal.

The results of a series of such experiments conducted at the same time as the analysis already given, are as follows:

Average composition of float on $CaCl_2$ solution 1.35 sp. gr.:

Vol. and Com. Mat.	Fix. Carb.	Ash.	Sulphur.
36.67	59.92	3.41	1.21

From these figures we learn that the coal treated had a fixed ash of 3.41 per cent., and 1.21 per cent. of fixed sulphur. Consequently the plant washed the large tonnage of coal treated in the five months to within one per cent. (0.92) of the best possible reduction in ash, and to within a third of one per cent. (0.3) of the best possible reduction in sulphur.

The loss in washing for the large amount of coal treated has been 13 per cent. plus 8 per cent., which is the difference in moisture, a total of some 21 per cent., and of this the impurity removed as ash and sulphur is 12 per cent., which leaves an actual coal loss of about 9 per cent. in the process.

The slate resulting from the washing process from the coarse jigs contains about 25 per cent. of good coal, and is therefore lifted by bucket elevator to the top of the jigs and re-washed in No. 4 coarse jig with the following results:

	Original Slate.	Washed Coal recovered from Slate.	Slate produced contains about 13% Coal.
Vol. and Com. Mat.	21.80	30.59	19.10
Fix. Carb...	37.10	51.61	24.40
Ash..	41.10	17.18	50.50
Sulphur...	4.06	2.79	9.07

This re-washed product is used about the plant under such boilers as are worked below their rated capacity.

A point of interest about the washer is the ingenious method of disposing of the slate which was introduced last spring by Mr. John Preston, the engineer who had supervision of this department. Hitherto the slate had been elevated to a bin in the storage tower, from whence, at proper intervals, it was removed on cars to a convenient dumping place. The present scheme is quite simple, and consists in flushing the slate from the jigs directly to the sea.

The following description of the equipment will explain the method in detail: An 8-inch pipe has been laid from the shore to the central condensing plant at No. 1 Colliery, and through it a 7-inch Gwynne centrifugal pump supplies salt water for condensing purposes. This pump has a rated capacity of 1200 imperial gallons per minute at 900 revolutions per minute, and is directly connected to a 50 horse power, 3-phase, 60-cycle, 220-volt induction motor located near the sea shore. The condenser is a 12 and 17 x 19 x 15 Worthington jet condenser, arranged to take steam from a Walker double compound compressor, a tandem compound fan engine, a tandem compound haulage engine, and a simple cylinder haulage engine; the four engines totalling up about 1500 horse power. The discharge pipe of the 7-inch centrifugal pump, which has a lift of 50 ft., is directly connected to the suction pipe of the air pump of the condensor. The air pump discharge delivers the salt water, after condensing the steam from the engines, to a 6-inch cast iron pipe, which passes through the wash plant, and is used for conveying the slate from the wash plant to the cliff, a distance of about 700 feet.

A valve controlling the amount of water supplied to this pipe is placed at the beginning of the pipe line with an overflow ahead of it, which carries away the difference between the amount of water delivered and the amount required. The slate enters the 6-inch cast iron pipe through a square hopper, the supply valve being sufficiently open to allow the water to half fill the hopper. The pipe is laid on a downward grade, varying from one to four per cent., towards the cliff. At the cliff, which it overhangs, there is a vertical leg about 26 ft. long, the latter gives a hydraulic gradient to the entire line sufficient to cause a flow of about 600 or 700 gallons per minute, when the pipe runs full bore; the resultant velocity causes all slaty material to be easily carried through the pipe.

In order to keep foreign material, such as bolts and spikes, from getting into the pipe and plugging it up, it has been found necessary to fit the hopper with a special grating, which consists of a cast iron plate, about six inches thick, perforated with 2½-inch diamond-shaped holes, the holes being V-shaped or zigzag in vertical section; this allows any round or square material up to about 1½ inches in diameter to pass through it, but will not allow any material having a length over 2½ inches to pass. Further precautions are taken to cope with clogging in the line by having special oblong openings cast in the pipe every few hundred feet apart. These openings have covers screwed on which can be removed at will. Should the pipe become clogged, lengths of small pipe, such as are commonly kept in stock, are coupled together and inserted into the opening immediately below the clog, and forced against the obstruction, the water pressure being kept in the meantime on the remainder of the pipe. Once started, the rush of water quickly clears the pipe.

Since the amount of water used for flushing purposes is already required by the colliery for condensing, the colliery and wash plant divide the pumping charges equally, and the cost of disposing of the slate by this method is very low.

The figures of a typical analysis of the coke from the washed coal may prove interesting. Such an analysis would be as follows:

Moist.	Vol. and Com. Mat.	Fix. Carb.	Ash.	Sulphur.
12.5	2.25	90.50	7.25	1.22

Thus it will be seen that this plant renders possible the manufacture of a coke which is eminently suitable for use in the iron blast furnace from a coal which unwashed would be unsuitable, and in addition utilizes for this purpose the less desirable, from the fuel point of view, portion of the coal, that is, the screenings.

The writer wishes to acknowledge his indebtedness to the management of the Nova Scotia Steel and Coal Company for permission to use the information given and for access to the records of their chemist. The author is, however, responsible for the preparation of the average analysis and for the conclusions drawn.

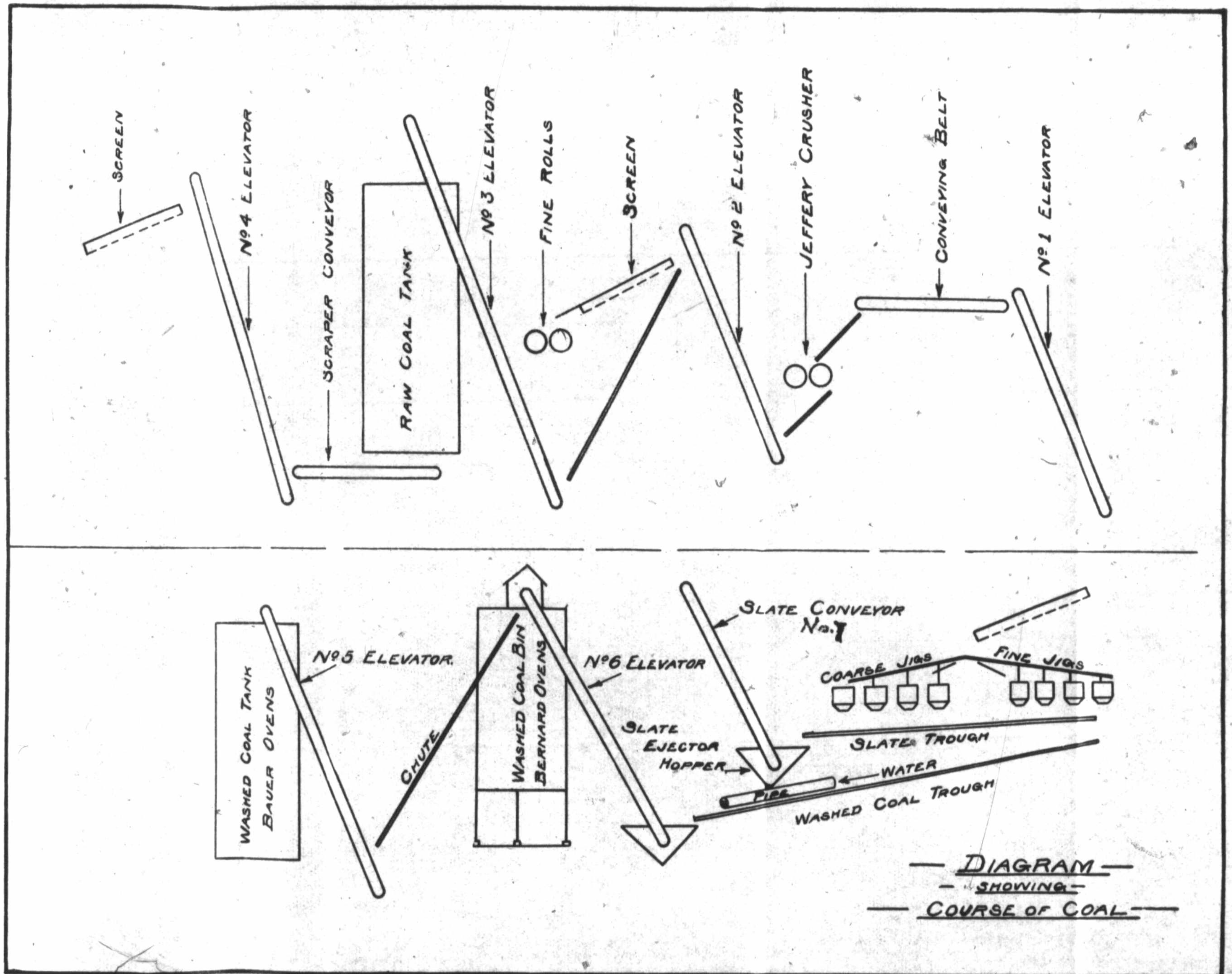

Diagram
Showing
Course of Coal