Mine-water Neutralizing Plant at Calumet Mine*

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(Lake Superior Meeting, August, 1920)

On Aug. 5 and 6, 1918, and Mar. 26, 1919, the writer made an investigation of the mine-water neutralizing plant at the Calumet mine of the H. C. Frick Coke Co. The object of this plant is to develop a process of treating the water pumped from the mines so that it may be rendered suitable for use at the power plants of the mines and also at the coke ovens; at the same time, eventually producing a byproduct which will have enough commercial value to provide a sufficient revenue to place the plant on a self-sustaining basis.

The Calumet mine is situated in Mt. Pleasant Township, Westmoreland County, Pa., on a branch of the southwest branch of the Pittsburgh Division of the Pennsylvania Railroad. It is about 6 mi. (9 km.) southeast of Greensburg, the county seat of Westmoreland County.

The coal, which is the Pittsburg or Connellsville seam, lies at a depth of about 200 ft. (60 m.) and is brought to the surface by means of a shaft. The output of the mine averages 200,000 tons of coal annually, all of which is made into coke, either at the ovens, at the mine, or at byproduct ovens. There are 260 coke ovens at the mine.

The continued development of the coal fields of Pennsylvania and the increased use of electric power in the operation of the mines has brought the problem of an increased water supply for the plants to the attention of the coal operators. This is especially true in the Connellsville coking region, where large quantities of water are used in quenching the coke at the ovens. Many of the streams receive the drainage from the mines; and as this water is highly acid and contains sulfur in various forms, some method of treatment is necessary to render it suitable for use at the plants of the mines. With this end in view, the H. C. Frick Coke Co., about 4 years ago, installed at its Calumet mine a plant for experimental purposes, in an endeavor to develop a process that would provide a maximum amount of suitable water at a minimum cost. From a purely technical point of view, the result of these experiments has been encouraging. The company is now endeavoring to place the plant on a commercial basis.

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DETAILS OF OPERATION

Calumet mine is drained by three boreholes 8 or 10 in. (20 to 25 cm.) in diameter, and 215 ft. (65 m.) deep, situated possibly 500 ft. from the main shaft. At the foot of the boreholes are four wooden-lined pumps (one 25 in. by 14 in. by 36 in. Lafayette pump; one 25 in. by 12 in. by 30 in., and two 20 in. by 12 in. by 36 in. Yough pumps) which deliver to the neutralizing plant an average of 1,000,000 gal. of mine water every 24 hr. An analysis of a sample of mine water as it comes from the boreholes and before it has received any chemical treatment is as follows:

ANALYSIS OF MINE WATER

	GRAINS PER U. S. GALLON	POUNDS PER 1000 GAL.
Non-incrusting solids:		
Sodium carbonate, Na_2CO_3	None	None
Sodium sulfate, Na_2SO_4	8.5	1.2
Sodium chloride, $NaCl$	0.9	0.1
Sodium nitrate, $NaNO_3$	None	None
Incrusting solids:		
Silica, SiO_2	3.8	0.5
Ferric oxide plus alumina, $Fe_2O_3 + Al_2O_3$	26.6	3.8
Ferrous sulfate, $FeSO_4$	5.5	0.8
Ferric sulfate, $Fe_2(SO_4)_3$	59.3	8.2
Calcium sulfate, $CaSO_4$	46.6	6.7
Magnesium sulfate, $MgSO_4$	8.3	1.2
Free sulfuric acid, free H_2SO_4	21.3	3.0
Total sulfur trioxide as sulfuric acid, SO_3 as H_2SO_4	165.7	22.3
Suspended matter	14.8	2.1

DESCRIPTION OF PLANT

Two of the boreholes are located on the opposite side of the railroad track from the main plant. Concrete towers about 18 ft. (5.5 m.) high have been erected over each borehole. Each tower is divided into two compartments, one of which acts as a standpipe into which the water is pumped from the mine below. When the water in this compartment reaches the top of the division wall, it overflows into the other compartment, from the bottom of which a drain leads to a tower between the two boreholes. This tower is similar to those erected over the boreholes, the water filling one compartment and overflowing into the second. From the effluent chamber, a covered concrete drain leads under the tracks and terminates in the mixing chamber of the plant. The entire arrangement is somewhat similar to an inverted siphon. The towers and drain are shown in Fig. 1. The general arrangement of the plant is shown in Fig. 2. The plant is in continuous operation 24 hr. per day; the average operating force, in addition to the superintendent, consists of eleven men.

Pulverizing, Storage, and Conveying Apparatus

The only material used in the process that is not furnished by the raw mine water is the limestone, which is shipped directly to the plant from the quarries in hopper cars and delivered at the outside of the storage shed in the form of screenings that will pass through a ½-in. mesh. The amount of limestone used per day depends largely on the amount of free acid in the water. It is estimated that for every ton of ferric oxide, ¾ ton of limestone is necessary.

These limestone screenings are elevated by a bucket conveyor to a storage bin having a capacity of from 80 to 100 tons. From this bin the screenings gravitate to a Lehigh-Fuller pulverizer, which crushes the limestone so that it will pass through a 200-mesh screen. From the pulverizer, another conveyor carries the limestone to a bin from which it drops on to a screw conveyor, which feeds it to a vertically inclined conveyor. This conveyor elevates the limestone to the mixing tank and drops it into the raw mine water as it comes from the boreholes. The amount of powdered limestone to be used is varied, depending on the amount of sulfuric acid in the water, by increasing or decreasing the speed of the electric motor driving the screw conveyor.

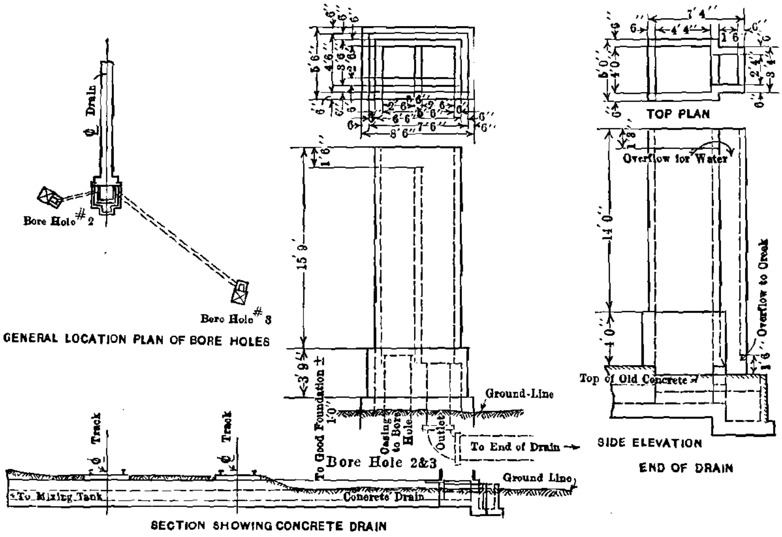

FIG. 1.—PLAN OF CONCRETE TOWERS AND DRAIN.

The water from the boreholes is delivered to the mixing tank by means of the inverted siphon arrangement described. As the water enters the mixing tank, the powdered limestone drops into it from the conveyor and is thoroughly mixed as the water passes over and under a series of baffles.

Chemical Reaction

In general, the reactions of the limestones on the mine water are as follows: The powdered limestone, $CaCO_3$, neutralizes the free sulfuric acid, H_2SO_4, present in the water, forming calcium sulfate, $CaSO_4$, water, H_2O, and carbon dioxide, CO_2. The basic ferric sulfate is more or less thrown out of solution, since it is held in solution by the acid.

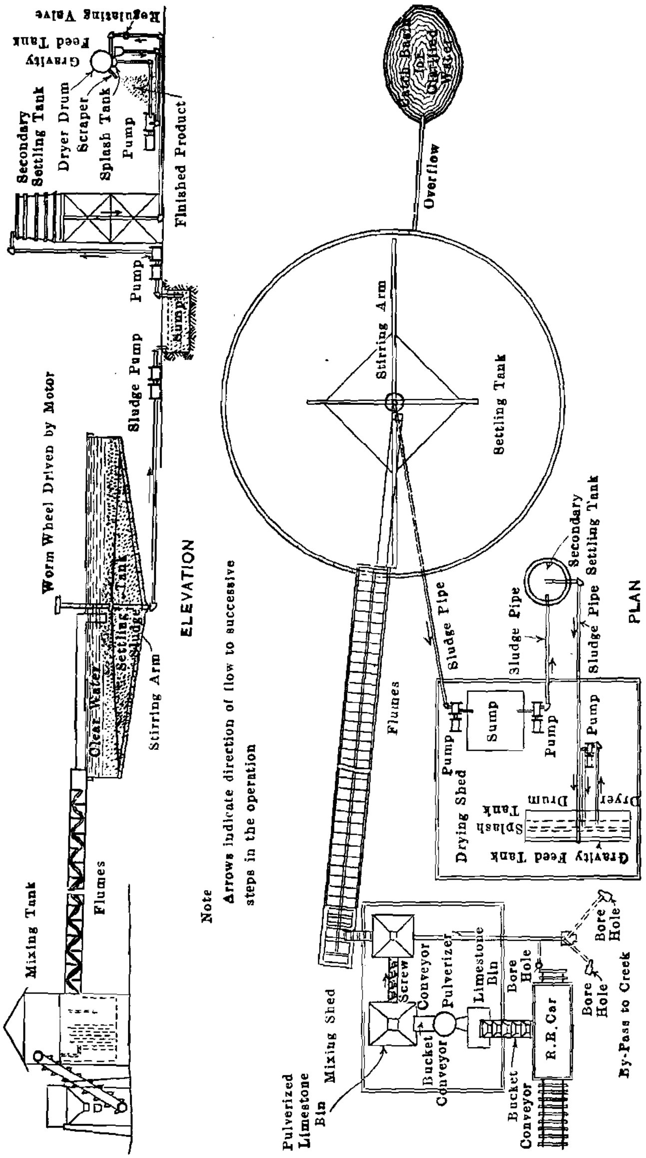

FIG. 2.—OUTLINE OF MINE-WATER NEUTRALIZING PLANT.

If the free acid is neutralized only, an almost true basic ferric sulfate is the precipitate.

After the free sulfuric acid is neutralized, if an excess of calcium carbonate, $CaCO_3$, is used, the ferric sulfate, $Fe_2(SO_4)_3$, is further reacted upon and decomposed into ferric hydrate, $Fe(OH)_3$, and calcium sulfate $CaSO_4$. However, the calcium sulfate produced is held in solution and does not get into the precipitate in harmful quantities. The resulting precipitate is known as hydrated oxide of iron and is the byproduct of the plant.

Aeration

Leading from the mixing tank to a Dorr thickener is a wooden flume, which is one of the essential parts of the entire process and the design of which is covered by patents. This flume is about 200 ft. (60.9 m.) in length and rests on bents about 8 or 10 ft. high and spaced about 10 ft. (3 m.) apart. It is practically composed of two wooden troughs, side by side, each trough 3 ft. wide and 2 ft. deep. Baffles 2½ ft. apart, alternately projecting from the bottom and from the top, impart to the current an undulating motion, which completes the mixing of the limestone and mine water commenced in the mixing tank and at the same time thoroughly aerates the entire mixture. An arrangement is provided by which any of the pulverized limestone settling in the bottom of the flume may be flushed into a separate tank, and the water drained. Following is an analysis of the treated mine water:

ANALYSIS OF TREATED MINE WATER

	GRAINS PER U. S. GAL.	POUNDS PER 1000 GAL.
Non-incrusting solids:		
Sodium carbonate, Na_2CO_3	None	None
Sodium sulfate, Na_2SO_4	11.6	1.7
Sodium chloride, NaCl	0.9	0.1
Sodium nitrate, $NaNO_3$	None	None
Incrusting solids:		
Silica, SiO_2	15.5	2.2
Ferric oxide plus alumina, $Fe_2O_3 + Al_2O_3$	56.6	8.1
Ferrous sulfate, $FeSO_4$	8.5	1.2
Ferric sulfate, $Fe_2(SO_4)_3$	None	None
Calcium sulfate, $CaSO_4$	131.2	18.8
Magnesium sulfate, $MgSO_4$	17.4	2.5
Free sulfuric acid, free H_2SO_4	0.5	0.1
Total sulfur trioxide as sulfuric acid, SO_3 as H_2SO_4	172.6	24.7
Suspended matter	100.3	14.3

SUSPENDED MATTER

	PER CENT.
Silica, SiO_2	7.6
Alumina, Al_2O_3	4.6
Ferric oxide, Fe_2O_3	41.3
Calcium oxide, CaO	7.0
Magnesium oxide, MgO	Trace
Sulfur trioxide, SO_3	19.1
Water, H_2O	12.4

Dorr Thickener

The flume is built on a 1.5 per cent. grade from the mixing tank and terminates at the center of a Dorr thickener, 7 ft. deep at the outer edge and 12 ft. in the center. When the flume reaches the center of the thickener, it turns down vertically so that the point of discharge is sufficiently below the surface to prevent the agitation of the clarified water.

With a flow through the thickener of 1,000,000 gal. (3,785,332 l.) every 24 hr., the capacity of the thickener will allow a settling period of about 4 hr. During this period, the ferric oxide held in suspension settles to the bottom, while the clarified water passes over the upper edges into collecting troughs, which carry it to a storage basin. From this basin, the water is used if required.

A vertical shaft through the center of the thickener is driven by a worm gear connected to an electric motor. Fastened to the lower end of the shaft are four arms placed at right angles to each other; two are 35 ft. (10.6 m.) long and the other two 16½ ft. These arms are parallel to the bottom of the thickener. On the bottom of each arm, and running diagonally across it, are riveted small steel angles which practically touch the bottom. These scrapers, as they are called, serve to concentrate the settled material at the center of the bottom of the thickener, as the arms revolve at a speed of one revolution every 5 minutes.

A short distance from the Dorr thickener is a building known as the "drying shed." A small diaphragm pump in this shed, connected to the underflow of the Dorr thickener, is used to draw the ferric oxide, or "sludge," from the thickener and discharge it into a sump. From this sump, a centrifugal pump lifts the sludge to an elevated tank outside of the drying shed for a further period of settling. At this stage of the process, the sludge contains about 75 per cent. of water and has the consistency of thick paint.

Drying Process

In the drying shed is a large drum dryer, manufactured by the F. J. Stokes Mach. Co. of Philadelphia, Pa., which is heated by steam at a pressure of 30 lb. (13.6 kg.). Just underneath the drum, and parallel to its axis, are two troughs, one of which is connected by a line of pipe to the elevated secondary settling tanks. At intervals of about 20 min., a valve in this pipe line is opened and the trough filled. The sludge from this trough gravitates to a small centrifugal pump a few feet in front of the dryer. This pump sends the sludge into the second trough with force enough to splash it against the hot outside surface of the drum. The water is evaporated by the heat as the drum slowly revolves, leaving the residue in the form of a very fine powder, which is scraped from the drum by a long knife-edged steel bar. This powder is yellow in color and is conveyed by a mechanical loader either to storage piles on the floor or into railroad cars for shipment.

ANALYSIS OF PRODUCT

	MOISTURE FREE PER CENT.
Silica, SiO_2	13.0
Titanium oxide, TiO_2	0.3
Aluminum oxide, Al_2O_3	10.3
Phosphorus pentoxide, P_2O_5	1.0
Ferric oxide, Fe_2O_3	37.1
Calcium oxide, CaO	13.2
Magnesium oxide, MgO	0.6
Potassium oxide, K_2O	1.0
Sodium oxide, Na_2O	0.7
Sulfur trioxide, SO_3	11.6
Combined water, H_2O, above 105° C.	4.8
Carbon dioxide, CO_2	6.4
Total	100.0

Changes in Plant

The plant, even at present, is of an experimental nature. Since the original installation, the company has made many changes in the mechanical operation, tending towards greater economy and efficiency, although the process remains the same. The most important change was the elevation of the mixing tank and flume, thereby obtaining a gravity flow to the Dorr thickener, at the same time placing the additional pumping head required upon the pumps in the mines.

In the first design, these pumps forced the water to the surface and it flowed by gravity through the mixing tank and the flume to a sump at the base of the Dorr thickener. From this sump, it was raised by a small centrifugal pump into the thickener. If for any reason the conveyor feeding the pulverized limestone into the raw mine water ceased to operate, more or less of the untreated water found its way to the small pump, with the result that the acid in the water attacked the metal and the pump was soon rendered useless. To overcome this condition, the concrete towers at the bore holes were constructed, the mixing tank and flume were elevated, and the work done by the small centrifugal pump was placed on the mine pumps. As these pumps are wood-lined, the injurious effect of the mine water is reduced to a minimum.

Results Obtained

The principal byproduct of the neutralizing plant is the ferric oxide extracted from the mine water. As has been stated, many of the water courses in this region contain a large amount of sulfur water, which, if used for quenching coke at the ovens, would undoubtedly have a tendency to discolor the coke and increase the sulfur content. It is well known that for blast-furnace purposes the amount of sulfur contained in the coke must be as low as possible. With additional treatment, this water may be rendered suitable for use in steam boilers.

In extremely dry seasons, such for instance as the summer of 1918, the treated water from the Calumet plant has been of material assistance. By using it for quenching coke, the company was able to conserve the fresh water stored in the reservoirs for domestic and power purposes. Before the Calumet plant was constructed, the mine water had been similarly treated in a crude way, when needed for quenching coke.

The possible advantage to be derived from the installation and maintenance of a plant similar to the Calumet plant over the common type of water-treating plants lies in the fact that the former produces a byproduct having a potential commercial value, while the sludge from the latter type has, as far as the writer has been able to ascertain, little if any value. If this byproduct can be made at a sufficiently low cost to meet competition from outside sources of supply of ferric oxide and the plant can be made to produce a revenue sufficient to pay the operating cost, the company will obtain an additional supply of water with little extra cost.

The plant at present is turning out 6 tons per day of ferric oxide. The amount of the byproduct depends entirely on the quantity of water pumped from the mine and the percentages of iron in various forms contained therein. During the war, when the importation of the natural ferric oxide was impossible, a ready market was found for the ferric oxide manufactured. Large shipments of this byproduct were made to the companies manufacturing artificial gas, for use in removing the hydrogen sulfide present in the gas. The problem now presenting itself is to so perfect the operation of the neutralizing plant that, if possible, competition with the European and domestic ferric oxide and iron borings can be successfully met.

Ferric oxide is also one of the chief ingredients in a number of the paints commonly used, and it is hoped that further experimentation will demonstrate ferric oxide to be of considerable value to the agricultural interests of the country and thereby furnish an additional market for the byproduct. The Calumet water-neutralizing plant, so far as the writer knows, is the only plant of its kind in this country which treats mine water in this manner.

Analysis of Various Mine Waters

In connection with experimental work[1] conducted by the Bureau of Mines on the action of acid mine water on the insulation of electric con-

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[1] H. H. Clark and L. C. Ilsley: Action of Acid Mine Water on the Insulation of Electric Conductors. U. S. Bureau of Mines *Tech. Paper* 58 (1913) 26 pp.

ductors, the chemical laboratory collected and analyzed a number of mine waters. The acidity and composition of mine waters from the same mine varies considerably at different times. However, the analyses of the samples collected are tabulated here in order to give a general idea of the composition of such waters. The waters tabulated vary considerably in acidity.

MINERAL ANALYSES OF SOME MINE WATERS COLLECTED AT VARIOUS COAL MINES, PARTS PER MILLION

Laboratory Number	Silica	Ferrous Iron	Ferric Iron	Aluminum	Calcium	Magnesium	Sodium	Chlorine	Total Sulfate Radical	Free Sulfuric Acid
10848	36	967	145	60	436	196	85	18	4755	442
10966	40	220	884°	°	162	77	75	25	6370	3662
11785	26	89	299	63	204	130	27	2	2374	93
11786	22	17	12		267	112	100	6	1406	106
11787	16	44	157	25	291	168	65	6	2234	135
11788	32	6	56		234	110	133	Trace	1562	203
11789	20	3	51		79	34	97	Trace	790	248
11790	29	Trace	11		232	118	66	7	1296	88
11791	48	11	915	148	300	197	54	2	4370	Trace
19825	64	6	320	111	295	79	21		2764	277

° Ferric iron and aluminum were not determined separately. 884 represents ferric iron as ferric oxide plus aluminum oxide, $Fe_2O_3 + Al_2O_3$. To convert parts per million to grains per U. S. gallon, multiply by 0.0583. To convert parts per million to pounds per 1000 gal., multiply by 0.00833.

The author is indebted to A. C. Fieldner, supervising chemist, and W. A. Selvig, assistant chemist, of the Pittsburgh Experiment Station, for supplying the table of analyses of various mine waters.

CONCLUSIONS

The problem of utilizing mine water has been under consideration by mine operators for some time, especially in the anthracite regions, where the quantity of water handled per ton of coal mined is great.

The treatment of mine water has been studied almost entirely from the viewpoint of prevention of damage to pipes, pumps, and boilers, and with a fair degree of success. The principal means of treating impure water used in boilers may be roughly classified as chemical, thermal and mechanical.

The first of these methods seeks, by so-called boiler compounds, either to free the water of mineral salts by precipitation or to remove the free acid by neutralization. The thermal treatment is, fundamentally, a boiling and condensing process and is commonly used when large amounts of carbonates of lime and magnesia are held in solution in water containing an excess of carbonic acid. By heating the water to the boiling point, the free acid is expelled and the salts precipitated. After sufficient time has elapsed to allow the precipitated salts to settle, the clear water may be pumped into the boiler. The third process is especially applicable to water holding in suspension fine particles of clay, sand, or organic matter. The water is first run into large settling tanks, where the suspended matter is allowed to settle, and then put through a filter, which will remove light organic matter.

Often a combination of these methods has been found advantageous. From the standpoint of the provision of a supply of pure water for boilers, these methods have proved more or less satisfactory. The objections to them are: The cost of the installation and operation of suitable purification plants places an additional burden on the production cost at the mine; none of them has in view the reclamation of any of the valuable elements held in either solution or suspension in the water.

The ideal plant would be one that sufficiently purified the water coming from the mines so that it could be used for domestic or steam purposes, and at the same time produced a byproduct of sufficient commercial value that the revenue derived from its sale would at least partly pay for the cost of the operation of the plant and the interest on the money invested therein. The Calumet plant is a long step toward such an ideal plant. A degree of purification sufficiently high to allow the water to be used at the coke ovens and, with additional treatment, in the boilers is attained. At the same time, about 6 tons per day of a byproduct is produced.

During the long dry spell of the summer of 1918, a number of mines in the bituminous coal regions were obliged to curtail their production for lack of water suitable for use in their power plants. At the same time sufficient water was flowing in near-by streams, which if purified would have kept the mines in continuous operation.

That there are valuable byproducts in ordinary mine water is shown in the operation of the Calumet plant. The ferric oxide is valuable for the purification of artificial gas. Sulfuric acid might be recovered although it can be produced more economically in other ways. However, the value of acid recovered might partly defray the cost of treatment and make it possible to purify water that could not otherwise be treated.

This water also contains some phosphorus and potassium, which may be of value in the fertilization of soils. The water from mines other than coal mines can also be utilized.

The foregoing cases are cited simply to show what might be accomplished when the treatment of mine water is studied from the viewpoint of reclaiming valuable products as well as from the viewpoint of obtaining a pure water supply. It would seem that, in many cases, a plant similar to the one at Calumet might prove to be an economical investment for a company whose surface water supply is in danger of being curtailed in the dry season, for the reason that by possibly producing enough revenue from the byproducts, the cost of operation will at least be partly met and therefore, will not add to the production cost of the coal. The striking advantage of the Calumet plant is its simplicity of construction and operation.

In the opinion of the writer it would be well worth investigation by any company which has before it the problem of the disposition of mine water and of a poor water supply.

DISCUSSION

Charles Haydock, Philadelphia, Pa. (written discussion).—The objects of the plant are stated to be the development of a process of treating the water from mines so that it may be rendered suitable for use at the power plants of the mines, and at the coke ovens, and at the same time produce a byproduct having enough commercial value to place the plant on a self-sustaining basis.

From the standpoint of the first object, the plant is not a success. The analyses of the treated water show the incrusting solids to be many times the accepted maximum permissible scale-forming content of boiler waters. Treating such a water by the customary methods would produce an effluent having such a tendency to foam as to be prohibitive under modern conditions of pressure and superheat. The writer is familiar with the plant and has been advised that the effluent has been used for boiler purposes only when it would otherwise have been necessary to shut down the mine. The harmful effects of using such waters for a short time cannot well be compared with the serious results produced by its regular use. The effluent, however, has been successfully used for quenching coke at such times as the supply of pure water has been inadequate.

As to the requirement that the plant be self sustaining, although no definite figures are given, the results appear encouraging. There is little available literature about byproduct recovery from water-purification plants though it seems probable that future development will be along such lines.

The commonly accepted opinion in the coal fields is that central-station electric service has been most frequently adopted to avoid the difficulties due to using mine waters for boiler purposes, and not as stated by Mr. Tracy. Further, elimination of the power plant simplifies the operation of the mine and, in some cases, substantial savings have been effected by purchasing current rather than generating it in the average mine-power plant, which usually is not of the more economical type.

J. R. Campbell,* Pittsburgh, Pa. (written discussion).—At the top of page 613, Mr. Tracy says that if the free acid is neutralized only, almost a true basic ferric sulfate is precipitated. Strictly speaking, this state-

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ment is not correct; a modified basic ferric sulfate is the result of either natural or artificial precipitation. W. H. Emmons[2] explains most logically the various reactions that take place in the sulfide enrichment of acid mine water.

A careful examination of the natural precipitate, commonly called sulfur mud, from acid mine water shows that usually it has approximately the following composition:

	Per Cent.		Per Cent.
Moisture	70.50	Alkalies	Not done
Silica	0.70	Iron oxide	63.43
Alumina	3.97	Loss on ignition	31.82
Lime	Nil	SO_3	14.44
Magnesia	Nil		

In this analysis, the iron salts are present approximately as follows: $Fe_2(SO_4)_3$, 24.07 per cent.; $Fe_2(OH)_6$, 71.95 per cent. This may be called a modified basic ferric sulfate, since the hydrolysis, or oxidation, of the ferric sulfate has not been completed according to the last reaction of the theoretical considerations. A true basic ferric sulfate of the formula $2Fe_2 (SO_4)_3 + 2Fe (OH)_3$, has the following composition: $Fe_2(SO_4)_3$, 78.9 per cent.; $Fe_2(OH)_6$, 21.1 per cent. This shows that there is considerable variation from the theoretical considerations. I have called the precipitate from mine water a modified basic ferric sulfate, or a modified ferric hydrate in some instances where the decomposition of the ferric sulfate has been very nearly complete.

The natural precipitate from acid mine water, in an air-dried condition, is valuable for the removal of H_2S from artificial gas, as shown by the following Kunberger tests:

	Dry, Per Cent.	Wet, Per Cent.
Moisture		30.70
Iron oxide	63.71	
First fouling		25.52
Second fouling		23,91
Third fouling		20.06
Fourth fouling		18.63
Fifth fouling		16.02

We take exception to the analysis of the artificial product produced by precipitation with powdered limestone, shown at the top of page 615. This analysis indicates a very high percentage of powdered calcite in the product, also the presence of ferric sulfate instead of ferric hydrate, which is almost inconceivable in view of the fact that gas-purifying material is being produced at the plant. There must have been an error either in sampling or in the analysis. Furthermore, this analysis does not agree with the one shown at the bottom of page 613, which is more nearly correct.

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[2] Enrichment of Sulphide Ores. U. S. Geol. Survey *Bull.* 529 (1913) 48.

A number of analyses of the artificial product made at the Calumet neutralization plant, and sold for gas-purifying purposes, have been made:

Analysis of Product	Per Cent.	Probable Combinations	Per Cent.		Per Cent.
SiO_2	12.47	SiO_2	12.47	Sand and clay	23.92
Al_2O_3	11.45	Al_2O_3	11.45		
CaO	7.45	$CaCO_3$	2.27	Calcite	2.87
MgO	0.60	MgO	0.60		
Fe_2O_3	39.43	$CaSO_4$	15.00	Gypsum	15.00
P_2O_5	1.10	$Fe_2(SO_4)_3$	6.20	Modified basic ferric sulfate	55.62
Ignition loss	26.30	$Fe_2(OH)_6$	49.42		
CO_2	1.00				
SO_3	12.54				

The average Kunberger test on the artificial product is about as follows:

	Dry, Per Cent.	Wet, Per Cent.		Wet, Per Cent.
Moisture		18.95	Fifth fouling	19.60
Iron oxide	38.30		Sixth fouling	16.13
First fouling		24.14	Seventh fouling	13.15
Second fouling		24.00	Eighth fouling	12.08
Third fouling		22.92	Ninth fouling	10.06
Fourth fouling		21.46	Tenth fouling	9.58

A complete mineral analysis of a sample of acid mine drainage and the probable combinations are:

Analysis of Acid Mine Drainage	Grains per U. S. Gallon	Probable Combinations	Grains per U. S. Gallon
Total solids	254.07	NaCl	0.96
Chlorine	0.58	Na_2SO_4	13.78
Silica	4.08	$CaSO_4$	68.76
Iron oxide	35.50	$MgSO_4$	24.35
Alumina	10.32	$Al_2(SO_4)_3$	34.57
Lime	28.33	$Fe_2(SO_4)_3$	52.03
Magnesia	8.16	$Fe_2(OH)_6$	19.66
Soda	6.53	Free H_2SO_4	17.13
Sulfur trioxide (total)	128.78		231.24
Total apparent acidity (H_2SO_4)	85.13		
Free acid (H_2SO_4)	17.13		

The iron salts are present in the acid mine drainage as a basic ferric sulfate or a modified basic ferric sulfate. Logically, as Mr. Tracy points out, these iron salts should be precipitated by the neutralization of the free acid present with powdered calcite or some other alkaline reagent. Any excess of powdered calcite will break down the ferric sulfate, as given by Mr. Tracy.

The artificial precipitate is very active and efficient for the removal of sulfuretted hydrogen from artificial gases. The activity and efficiency seems to be due to its alkalinity and colloidal character, it being freshly precipitated material. The precipitate is being used successfully in a commercial way and shows much higher absorption of H_2S than most oxides, like iron borings oxides, bog ore, and other natural ores. In comparative tests, the precipitated oxide showed 40 per cent. more efficiency than iron borings.

If the plant is practicable and economical on a much larger scale than the experimental one described, this process merits the consideration and coöperation of the gas companies. It would seem unfortunate if this valuable byproduct from mine water could not be recovered from acid mine drainage economically, in view of its potential value in the purifying field when artificial gas supplants natural gas entirely, due to its rapid depletion. It is to be hoped that this byproduct from mine water can be developed as surely as the byproducts from coal itself—it really is a byproduct of coal in the final analysis.

W. A. Selvig,* Pittsburgh, Pa. (written discussion).—The iron that is precipitated from acid mine water on standing, dilution or partial neutralization of the free sulfuric acid is probably a mixture of basic ferric sulfates and ferric hydroxide. Analyses of natural precipitates from mine water show an insufficient sulfur content to form true basic sulfates with the iron present.

Mr. Campbell states that he takes exception to the analysis of the artificial product produced by precipitation with powdered limestone, shown at the top of page 615. The analysis of the sample as submitted by Mr. Tracy was carefully made by a skilled analyst and the writer is confident that it is correct of the sample as submitted.

Mr. Campbell's statement that the analysis in question indicates the presence of ferric sulfate instead of ferric hydrate is hardly justified. Assuming that the hypothetical combinations of the ingredients of the artificial precipitate as calculated by Mr. Campbell from his analysis are correct, the writer by the same method of calculation obtains from the analysis made by the Bureau of Mines: $Fe_2(SO_4)_3$, 7.3 per cent.; $Fe(OH)_3$, 45.8 per cent.

It is rather misleading, however, to state that such a precipitate contains ferric sulfate $Fe_2(SO_4)_3$ as this salt is very soluble in water. The writer prefers to think that the sulfur that may be present combined with the iron is in the form of basic sulfates, possibly $Fe_2(OH)_4SO_4$ or $Fe_2(OH)_2(SO_4)_2$ and that the natural precipitate consists largely of ferric hydroxide $Fe(OH)_3$ together with a smaller amount of basic ferric sulfates.

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L. D. TRACY (author's reply to discussion).—In reply to the discussion of Mr. Haydock, the author would say that at no time has he claimed that this treated water was suitable for boiler use. In fact, he says that "with additional treatment this water might be used for boiler purposes." The author agrees with the statement that "Treating such a water by the customary methods would produce an effluent having such a tendency to foam as to be prohibitive under modern conditions of pressure and superheat." But in these days of chemical research it does not seem an insolvable problem to devise methods, other than the customary ones now in use, by which water, similar in analysis to that referred to, may be rendered fit for boiler purposes. There are, however, other uses for water around a power plant than for making steam, one of the most essential of which is for condensation and cooling purposes. In large plants, this is an important item and the use of untreated water, as found in most of the streams, would soon render the steam pipes leaky and unfit for use.

Mr. Haydock states that the central station electric service has been frequently adopted to avoid the difficulties due to the use of mine waters for boiler purposes. There is a tendency at the present time to design large power plants to be located at or near the coal mines, in order to save the transportation costs of fuel. It is a fact that in many of the coal fields the water supply near the mines is more or less contaminated, so that with large central stations, the question of suitable water for boiler purposes is important. In fact, in times of drouth it is necessary to conserve as much as possible the pure surface water so that it can be used in boilers; and by neutralizing this mine water, and thus rendering it suitable for condensation and domestic purposes, an important step in this conservation will have been taken. Whether or not the plant is a success is a question of individual judgment, however, it has been in operation for almost six years under the H. C. Frick Company.