stage.[67] During the past year a commercial-scale plant using this process was installed at one of the mines in the Birmingham, Ala., district. Since its installation, this plant has been producing about 100 tons per day of excellent-grade, cleaned and dewatered coal from a dewatering-screen underflow which was formerly too high in ash to be suitable for use as coking coal. The feasibility of using the process at several other plants is being investigated. Prospects for making the process applicable to the treatment of fine-size raw coal are very encouraging; and, if it can be adapted to this purpose, it is believed that it will be a practical solution to many of the sludge and slurry problems with which the coal-preparation industry is confronted. Furthermore, it should serve to increase considerably the recovery of coking coal throughout the industry.

New Machine for Thickening Coal Slurry

A cyclone device employed to thicken the loess suspension in the loess heavy-medium coal-cleaning process developed by the Netherlands State Mines has been studied by the Bureau of Mines after one of its staff observed its operation in the Netherlands in 1945. The first experimental work with the cyclone conducted by the Bureau was an investigation of the unit functioning as a heavy-medium cleaner for fine coal. Further investigation dealt exclusively with operation of the cyclone as a thickener of coal slurries - a new application of this device that promises wide usefulness under American conditions.

Figure 21 illustrates the construction of one of the cyclones used in this investigation. In operation the slurry of water and fine coal is pumped through the tangential feed nozzle and thereby caused to rotate or whirl. Under the influence of the centrifugal force developed by the rotary motion, the solid particles are thrown to the wall of the conical section and forced downward along the wall until they pass out of the cyclone through the underflow or bottom opening. The water, largely freed of solid particles, overflows through the central opening in the orifice plate at the top and leaves the cyclone by way of the overflow chamber.

Figure 22 is a photograph of the laboratory installation. The cyclone is mounted over a 50-gallon conical tank, which serves as a collecting sump for the feed pump. Thus the cyclone is in a closed circuit, both overflow water and underflow coal falling directly into the conical tank and from there being recirculated through the cyclone. The centrifugal pump is provided with a variable-speed drive capable of developing from 0 to 50 psi pressure at the feed nozzle of the cyclone.

Table 6 presents the results of two tests made on the same slurry with identical cyclone adjustments; in test 82 the underflow was a vortex, while for test 81 the underflow was converted to sausage form. In the test made with vortex operation 12.3 percent of the water present in the feed entered the underflow product, and the underflow contained 59.4 percent solids. A sausage-type underflow always contains more solids than does a vortex underflow.

---

[67] Gandrud, B. W., and Riley, H. L., A Combination Cleaning and Dewatering Process for Treating Fine Sizes of Coal. Preliminary Report: Bureau of Mines Rept. of Investigations 4306, 1948, 25 pp.

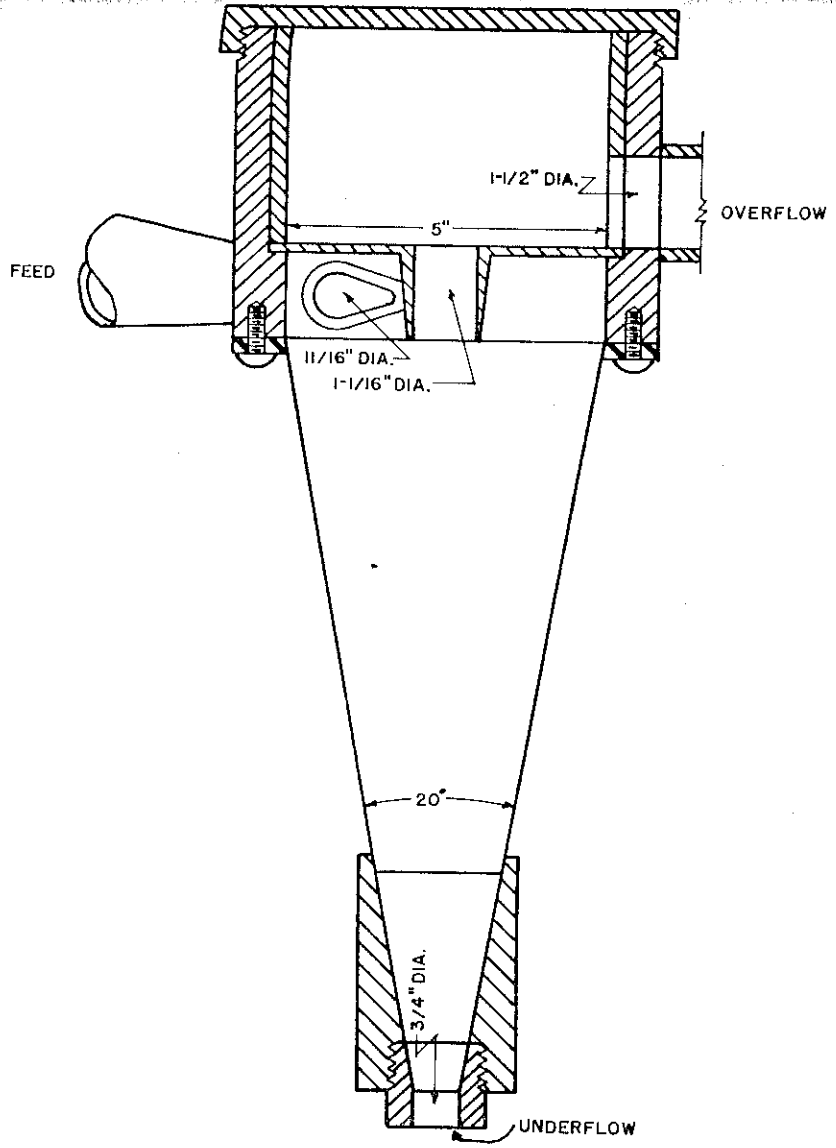


Figure 21. - Construction of cyclone.

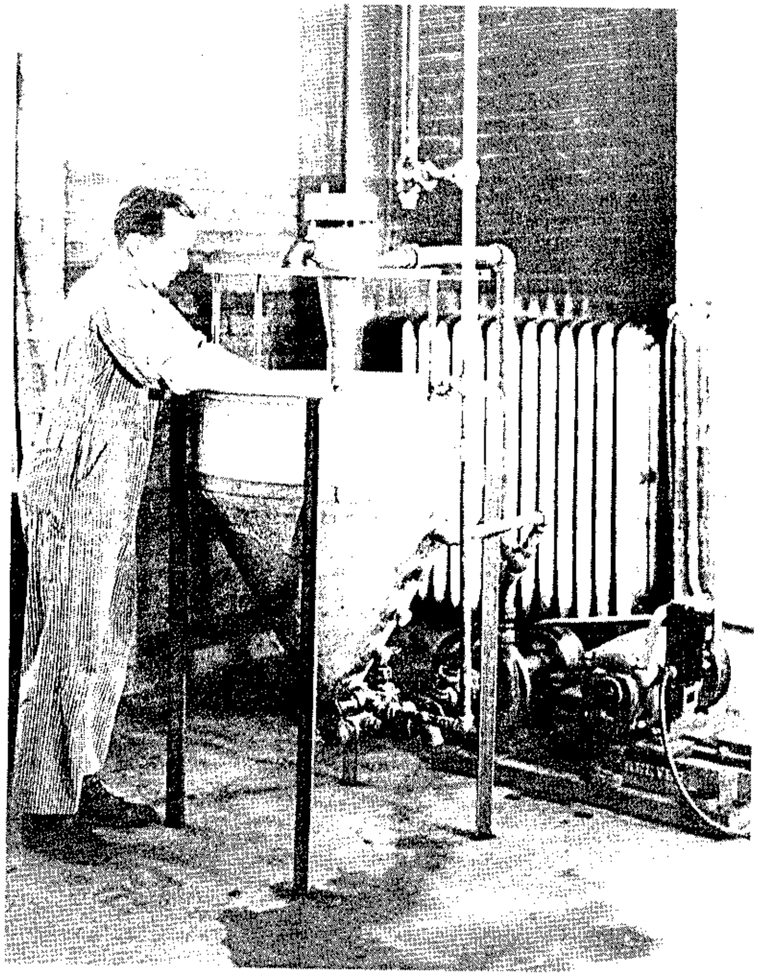


Figure 22. - Cyclone test unit arranged for closed-circuit operation.

TABLE 6. - Comparison of cyclone operation with vortex- and sausage-type underflows

	Test 82, vortex-type underflow			Test 81, sausage-type underflow		
	Feed	Over-flow	Under-flow	Feed	Over-flow	Under-flow
Solids, percent	8.0	0.8	39.5	8.0	1.0	59.4
Distribution of total solids, percent	100.0	7.7	92.3	100.0	10.8	89.2
Distribution of water, percent	100.0	87.7	12.3	100.0	94.7	5.3
Screen analysis of solids, percent:						
35 to 48	24.4	.0	26.4	23.8	.0	26.7
48 to 65	12.7	.0	13.8	20.0	.0	22.4
65 to 100	23.5	.1	25.5	19.2	.1	21.5
100 to 150	9.1	.0	9.8	9.4	.0	10.5
150 to 200	9.6	.4	10.4	8.6	.8	9.6
200 to 270	2.6	.2	2.8	2.6	1.5	2.7
270 to 400	4.6	1.1	4.9	4.4	8.2	3.9
Under 400	13.5	98.2	6.4	12.0	89.4	2.7
Distribution of solids by sizes, percent:						
35 to 48	100.0	.0	100.0	100.0	.0	100.0
48 to 65	100.0	.0	100.0	100.0	.0	100.0
65 to 100	100.0	.0	100.0	100.0	.0	100.0
100 to 150	100.0	.0	100.0	100.0	.0	100.0
150 to 200	100.0	.3	99.7	100.0	1.0	99.0
200 to 270	100.0	.8	99.2	100.0	6.2	93.8
270 to 400	100.0	1.7	98.3	100.0	20.4	79.6
Under 400	100.0	56.1	43.9	100.0	80.0	20.0

The figures at the bottom of table 6 show the percentage of each size fraction of the solids entering the overflow water and the percentage recovered in the underflow product. The only noticeable difference in the recovery of solids obtained in operating the cyclone with sausage- and vortex-type underflows occurs in the material finer than 200-mesh. There was virtually no loss of solids coarser than 200-mesh in either test, but the material finer than this size was recovered more efficiently when the cyclone was operated with a vortex underflow. However, in treating a slurry containing only a moderate quantity of extreme fines the recovery obtained with the two types of underflows is substantially the same.

The investigation of the cyclone demonstrated that its capacity is several hundred times that of conventional thickeners. Coal slurries can be thickened to a solids content of 60 to 65 percent. The cyclone effects virtually complete recovery of solids coarser than 200-mesh but recovers only about one-third of the material finer than this size, with a resultant inability to produce a clear overflow water. Since the cyclone is inexpensive to construct, has no moving parts, and is cheap to operate, it should find a number of applications, not only in the coal-washing field, but throughout the whole mineral industry.

Washing Tests of Oregon Coal

At the joint request of the Municipal Water Board, Eugene, Oreg., and coal-land owners, an intensive investigation was made of the washing characteristics of a coal from the locally important Beaver Hill bed, Coos County, Oreg., with the ultimate object of supplying fuel for a proposed coal-burning steam-electric power plant, constructed at the mine mouth, to relieve the shortage of electric power in the area. One of the questions upon which the proposal hinged was that of the quality of the washed coal that could be delivered by the mine. Although coal has been washed at the mine for the past few years, it was not felt that the mill performance was indicative of what could be expected from a modern washery.

A 12-ton sample of coal from the Southport mine was crushed to pass a 2-inch square-hole screen and washed in a laboratory-size, 3-cell, 1-compartment, Baum-type jig which has a capacity on this coal of about 5 tons per hour. Samples of the raw coal and of all jig products were subjected to float-and-sink tests and ash analyses to permit evaluation of the laboratory jig performance in terms of full-scale plant operation.

The yield of washed coal in terms of the jig feed was 83.2 percent; and, taking into account the 5.1 percent of rock picked out at the mine, the washed-coal yield was 79.0 percent of the original raw coal. The washed coal contained 11.0 percent ash, moisture-free basis, which is equivalent to 10.0 percent ash on a bed-moisture basis. The heating value of the coal was 9,760 B.t.u. per pound on a bed-moisture basis or 11,650 B.t.u. on a moisture-free basis.

Washing Tests of Alabama Coal

Washability studies[68] of coals from the Clark and Gholson beds at Boothton, Ala., indicated that, if the coals were washed separately in plants combining jigs and tables, the Gholson bed should give a 4-inch to 0 washed coal of about 3.7 percent ash and the Clark, a 4-inch to 0 washed coal of about 6.4 percent ash. The yields of washed coal depend largely on the amount of rock introduced into the run-of-mine coal during mining operations. On the basis of the run-of-mine samples used in this washability study, the Gholson bed would give a yield of about 86.9 percent of the feed to the washer as washed coal. The corresponding figure for the Clark bed would be about 68.7 percent of the washer feed as washed coal. Analyses of seam samples showed that both coals have a low-sulfur content.

Preparation Characteristics of Maryland Coals

A comprehensive survey of the preparation characteristics of American coals was initiated by publication of data on Maryland coals.[69] Sizing tests and float-and-sink tests of representative samples of the minable coal beds in the Georges Creek, Upper Potomac, and Castleman Basins indicated that some of these older beds, below the Pittsburgh, can be made suitable for use in coking-coal blends with high-volatile coals. Others of these beds, not now fully developed, could be prepared for efficient industrial and domestic fuel.

The Kittanning beds respond best to washing. Treatment of these coals by conventional washing processes could produce a grade of coal up to current metallurgical standards with respect to sulfur and ash content. In some areas the Lower Bakerstown and Mount Savage beds would yield a low-sulfur product by washing, but careful selection of mining areas and treatment facilities would be necessary. All of these coals respond favorably to fine crushing to free the product of associated impurities.

---

[68] Gandrud, B. W., and Riley, H. L., Washability Study of the Clark and Gholson Coal Beds at Boothton, Ala.: Bureau of Mines Rept. of Investigations 4160, 1947, 11 pp.

[69] Crentz, W. L., and Fraser, Thomas, Preparation Characteristics of Maryland Coals: Bureau of Mines Tech. Paper 701, 1947, 66 pp.

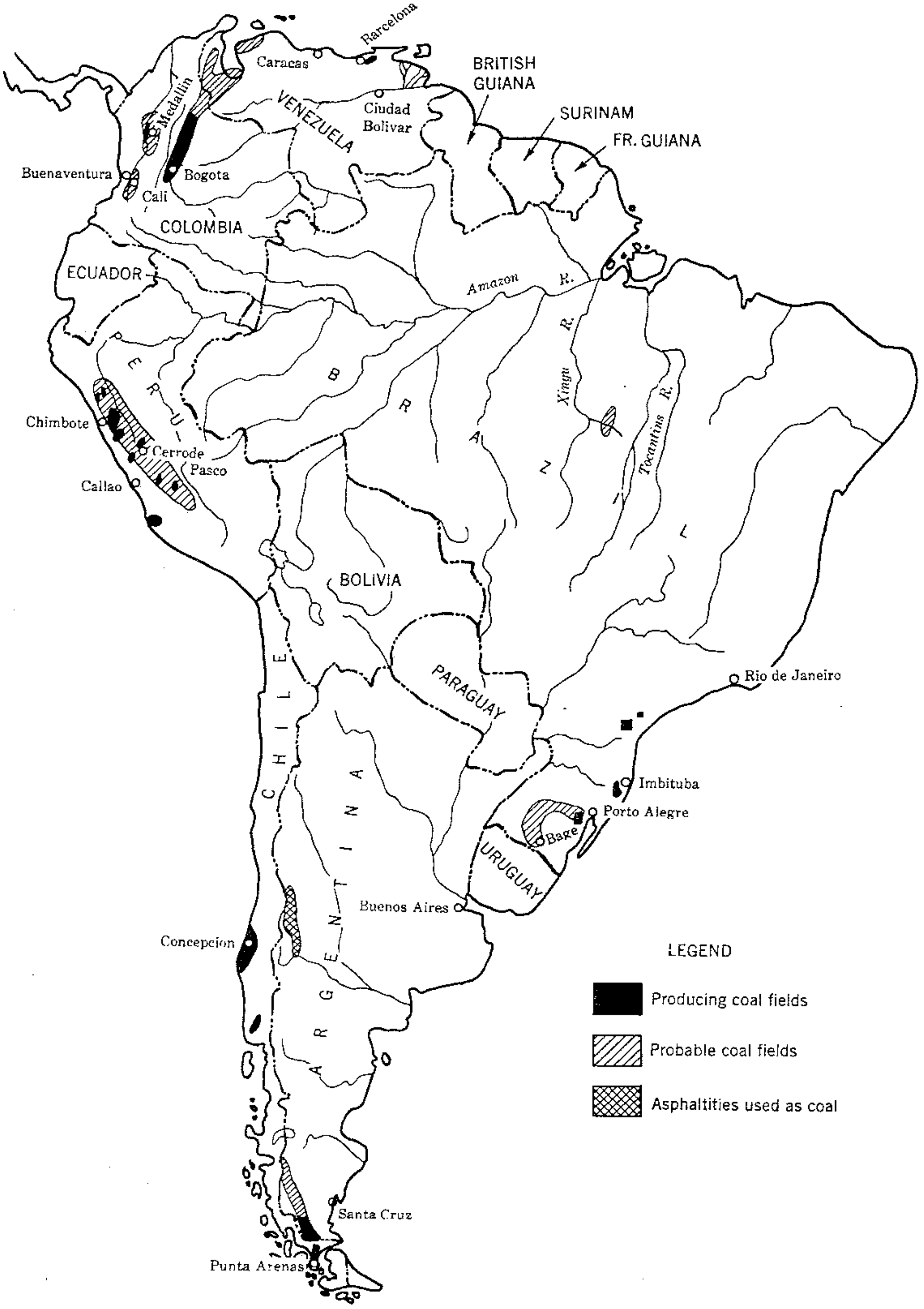


Figure 23. - Principle coal-producing fields of South America.

The Upper Bakerstown bed can be improved by washing, but the top bench would have to be discarded in many cases. A washed coal analyzing less than 8 percent ash and 1.5 percent sulfur can be obtained by washing at commercial gravities.

The Lower Bakerstown and Upper Freeport beds are amenable to washing if the operation is restricted to the bottom bench in each instance.

Preparation Characteristics of Certain Peruvian Coals

A study of preparation characteristics of the anthracites in the Santa River Valley of Peru[70] disclosed that extensive minable deposits of anthracite available through the Pacific coast port of Chimbote in northern Peru can be prepared to form a high-grade domestic and steam coal suitable to the South American trade and to users of special fuels on the Pacific coast of the United States.

A somewhat related source of low-volatile coking coal occurs in the Oyon[71] coal field northeast of Lima. Washability and coking tests indicated that the coal from several deposits in this general area, high on the western slope of the Continental Divide in the district of Cajatambo, is suitable for blending with high-volatile coking coals of the Sunnyside, Utah, type to improve the coke structure. Float-and-sink tests of a sample of the coal showed it to be readily responsive to mechanical cleaning. A prepared product of 5.0 percent ash and 0.90 percent sulfur can be obtained by treating the coal represented by this sample. Carbonization tests of the Oyon coal made in the 13-inch BM-AGA retort at 900° C. gave the following yields of products: Coke, 83.7 percent; gas, 10,200 cubic feet per ton of coal; tar, 4.7 gallons per ton; light oil, 1.27 gallons per ton; and ammonium sulfate, 8.7 pounds per ton.

In connection with cooperative Latin American Projects, of which the above surveys were a part, a brief general survey of coal resources and activities was prepared for the Pan American Institute of Mining Engineering and Geology.[72] Figure 23 shows the principal coal-producing fields of South America.

Upgrading of Marginal Coking Coals

Upgrading of marginal coking coals by preparatory treatment is designed to extend the supply of metallurgical fuel. One of the most promising directions for research is the reduction of the sulfur content of high-sulfur coals that are otherwise adapted to coking. This is especially important in the United States because of the large reserves of coking coal in the Pittsburgh area that are too high in sulfur to meet current specifications.

---

[70] Fraser, Thomas, Preparation Characteristics of Anthracites in the Santa River Valley, Peru: Bureau of Mines Rept. of Investigations 4200, 1948, 31 pp.

[71] Fraser, Thomas, and Davis, J. D., Preparation and Carbonization Characteristics of Low-Volatile Coal from Oyon Region of Peru: Bureau of Mines Rept. of Investigations 4222, 1948, 9 pp.

[72] Fraser, Thomas, Coal in South America: Pan American Inst. Min. Eng. and Geol., Tech. Paper 6, 1948, 16 pp.

A fundamental study of the forms of sulfur in the very low gravity fractions[73] of some important bituminous coals was made to ascertain if there were any significant differences in the inherent sulfur content of the different petrographic components of the coal that are separable by carefully controlled specific-gravity classifications. The specific-gravity fractions showed only very minor variations (fig. 24) in organic sulfur content, mostly within the range of experimental error. These variations are too small and irregular to have practical importance in preparing the coal. With respect to pyritic sulfur, which is the predominant form in most of our coking coals, there is a progressive improvement, with decrease in specific gravity continuing into the very light fractions as shown in figure 25. This indicates possibilities of substantially improving the grade of the coals if commercially applicable methods can be developed for controlled separation of the raw-coal mixtures at very low gravities.

Drying Low-Rank Coals

Flash-Drying Process

During 1946 and 1947, considerable interest was focused on the problem of drying low-rank coals for industrial use. Because of pending shortages of natural gas in the northeastern Wyoming and Montana area, several large users of gas in the Rocky Mountain region, particularly power and cement plants, were obliged to convert to subbituminous coal. Industrial interest in the improvement of subbituminous coal and lignite encouraged an accelerated study of the drying problem for both cement-burning and briquetting.

A study of drying plants operating on subbituminous coal showed that the rotary driers used at cement plants were inefficient and costly, although the cement kilns were operating satisfactorily on the processed coal. One drying plant reduced the moisture from 31 to about 20 percent in a single-stage rotary, while the other plant reduced moisture from 12 to 6 percent in a two-stage drier. It was indicated that rotary drying processes, normally used for removing surface moisture from coal, are fundamentally unsuited for the low-rank coals because the time of contact in the drier and the temperatures developed are not sufficient to remove the bed moisture.

Experiments in the laboratory revealed that bed moisture could be removed from fine coal in a few seconds by flash-drying with hot gases. Accordingly, this phase of drying low-rank coals was studied further, and investigations were made to determine if flash-dried subbituminous coals were suitable for briquetting. A pilot plant for handling about 2 tons of coal per day was built, as illustrated in figure 26. Several tests proved that subbituminous coal up to 1/16-inch size can be flash-dried in 1 to 2 seconds to remove 90 percent of the bed moisture at an indicated efficiency of about 90 percent. It was further proved that drying coal by this method was a straightforward thermal and materials-handling problem, and large plants could be designed from the data developed.

The experimental work on flash-drying 1/16-inch x 0 coal was done in cooperation with the Natural Resources Research Institute of the University of Wyoming, where a pilot plant for briquetting coal is in operation.

---

[73] Fraser, Thomas, and Crentz, W. L., Sulfur in Low-Gravity Fractions of Some Bituminous Coals: Bureau of Mines Rept. of Investigations 4167, 1947, 6 pp.

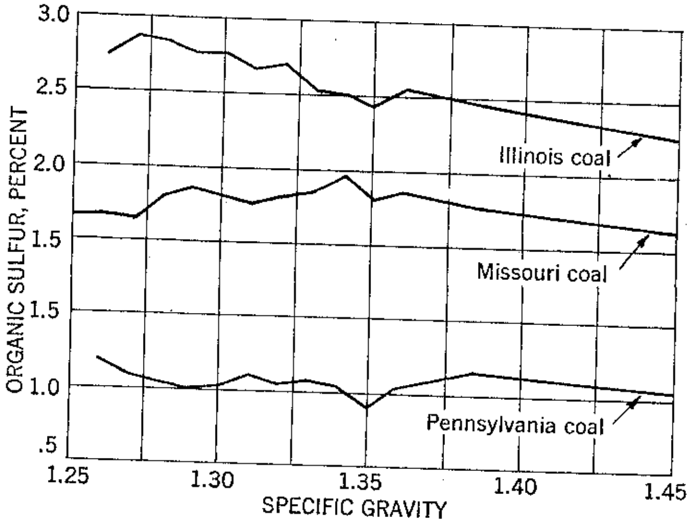


Figure 24. - Organic sulfur content of various specific-gravity fractions.

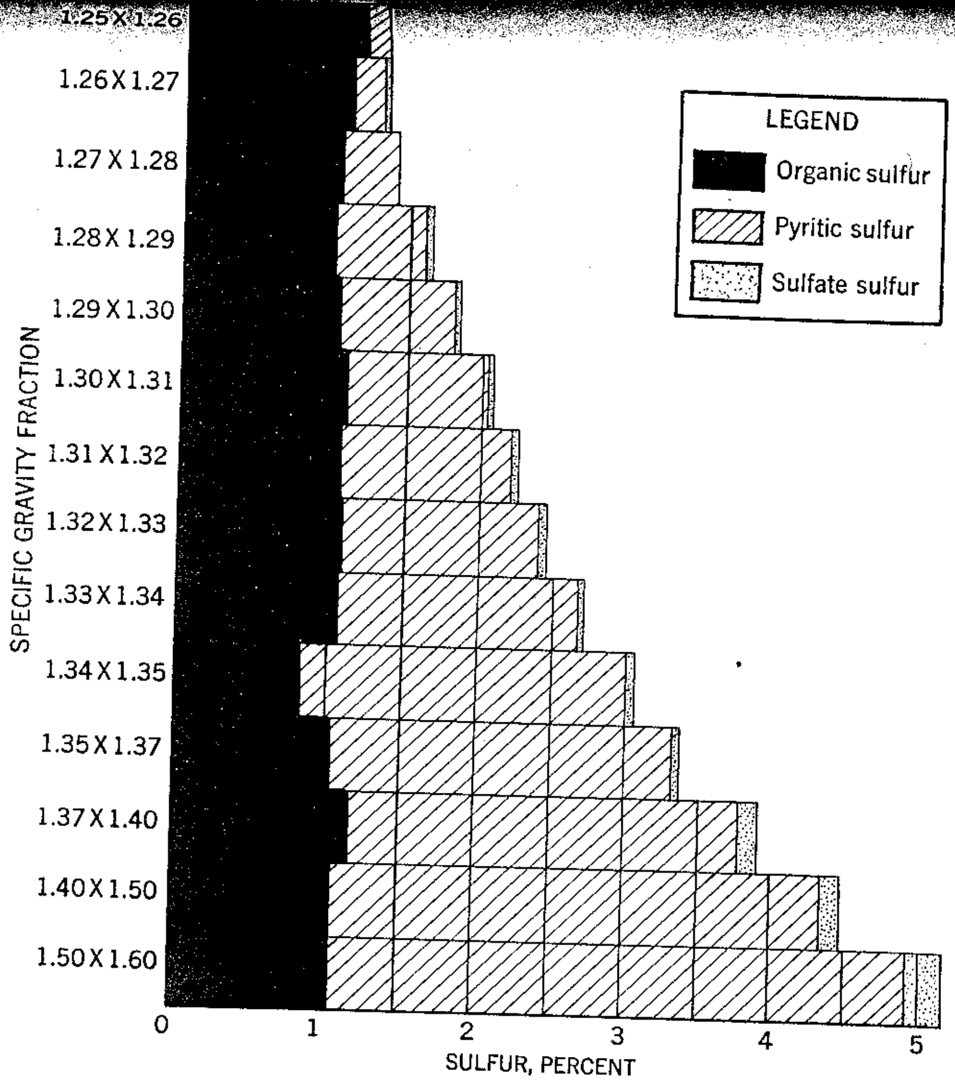
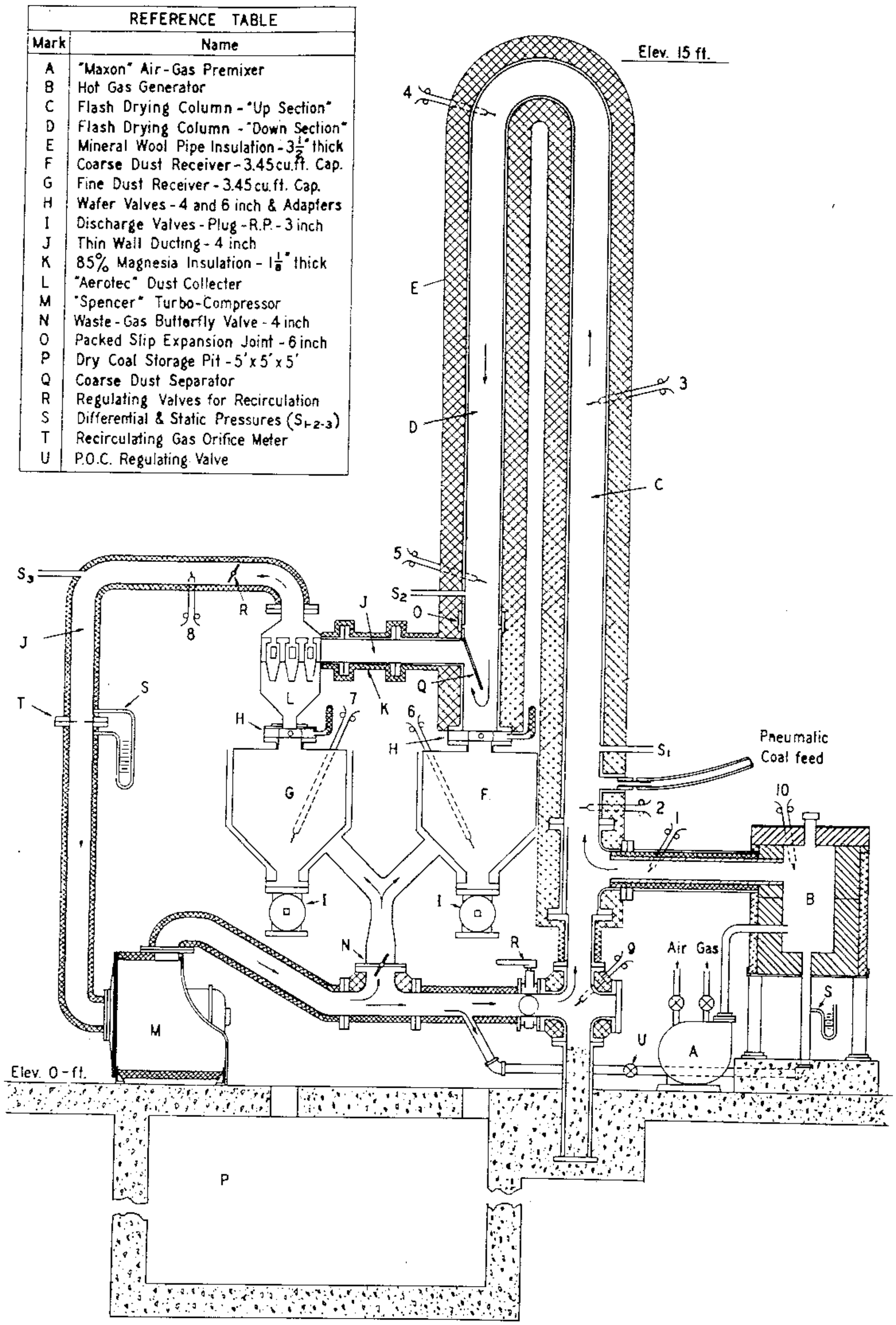


Figure 25. - Variations of forms of sulfur in specific gravity fractions of a Pennsylvania coal.



REFERENCE TABLE

Mark	Name
A	"Maxon" Air-Gas Premixer
B	Hot Gas Generator
C	Flash Drying Column - "Up Section"
D	Flash Drying Column - "Down Section"
E	Mineral Wool Pipe Insulation - $3\frac{1}{2}$" thick
F	Coarse Dust Receiver - 3.45 cu. ft. Cap.
G	Fine Dust Receiver - 3.45 cu. ft. Cap.
H	Wafer Valves - 4 and 6 inch & Adapters
I	Discharge Valves - Plug - R.P. - 3 inch
J	Thin Wall Ducting - 4 inch
K	85% Magnesia Insulation - $1\frac{1}{8}$" thick
L	"Aerotec" Dust Collecter
M	"Spencer" Turbo-Compressor
N	Waste-Gas Butterfly Valve - 4 inch
O	Packed Slip Expansion Joint - 6 inch
P	Dry Coal Storage Pit - 5' x 5' x 5'
Q	Coarse Dust Separator
R	Regulating Valves for Recirculation
S	Differential & Static Pressures (S_{1-2-3})
T	Recirculating Gas Orifice Meter
U	P.O.C. Regulating Valve

Figure 26. - Flash drier for fine coal, Golden, Colo.