MINING METHODS IMPACT ON COAL PREPARATION PLANT DESIGN

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THE INTERRELATIONSHIP OF COAL MINING AND PREPARATION

Mining methods have a significant impact on the design of a coal preparation plant. One obvious impact is the effective size distribution of the raw coal. Other impacts are the moisture content and reject material included with the coal. The choice of a mining method for a specific coal deposit depends on technical economic needs and geological conditions--what is desirable and what is possible. Selection of the mining method will have the most significant impact on raw coal qualtiy and hence coal preparation.

Coal preparation begins with the mining and production of a quality product in a true interrelationship of mining methods and coal preparation processes. The method of mining has a strong impact on the design of a coal preparation plant. Coal mining with pick and shovel allows a careful separation of coal and waste material to be performed directly at the mine face. Productivity in tons per man-hour is low. Improved productivity comes from mechanization, but mechanization also increases the amount of impurities included with the run-of-mine coal. Experience in the United States has been that as the transformation from hand mining to mechanical means has increased, additional coal preparation has been required to maintain the same coal quality levels. As coal mining extends to thinner coal seams a higher proportion of top and bottom material is included with the coal. This extra material increases the amount of reject that must be handled in a coal preparation plant. Increased mechanization usually means heavier mining machinery which will dig into soft bottom, water sprays to prevent dusting, and rapid rate of mining advance causing deviation from the mining horizon which all add to the impurities in the raw coal. With modern underground mining methods very little selective mining can be expected at the face, even if it is considered desirable. Surface mining can be very selective and reject thin amounts (greater than 6") of waste material that interlie the coal seam, but as higher tonnage operations are installed, the amount of extraneous material that is included with the mined coal is increasing. All these trends are beginning to require greater amounts of coal preparation to assure a consistent quality product for final utilization and to decrease the transportation costs involved with shipping the waste material from the mine to the utilization site.

COAL PREPARATION BEGINS DURING EXPLORATION

Table I shows what must be taken into consideration by the engineers who design the mining systems and the geologists who advise them. Physical factors cannot be changed; they represent what we have to work with. The geometry of the deposit might be simple or complex, the geology of the deposit and its surroundings gives us geotechnical limits within which we must work. The geography presents some opportunities and restrictions in regard to methods of entry and development.

Technological factors spell out the conditions under which the mining method must be made to work. An unsafe method is of course unacceptable. A highly sophisticated method requires that a cadre of skilled miners and mechanics be found locally or brought in. An inflexible mining method may be efficient only within a very narrow range of operating conditions. If a method has a well established precedent it can be designed full scale. If not, a smaller scale or pilot operation may have to be tried first.

A large portion of the factors that impact on mine planning and design can be seen to be geologically related. Thus since coal preparation begins with the mine design and planning, it must also be shown that coal preparation begins with the initial exploration program for the coal operation. The mining method strongly affects the coal preparation process and the geological factors of the coal deposit affect the mining method. A exploration program then has a very strong impact on the coal preparation plant and the coal preparation processes.

There are four basic considerations when a coal exploration program is initiated: Define the end use of the coal; define the reserves; determine the geologic characteristics of the mining block; and determine the preliminary quality parameters. A definition of the end use of the coal is important in that how the coal is mined and processed affects the quality, and the geological analysis of the deposit affects the mining. Knowing what the coal is to be used for keys the geologist into what factors are important in his exploration and analysis. Once the end use has been defined the overall reserves that are available for mining must be explored for and delineated so that the true size of the deposit is known. This is important from the fact that some mining methods, in particular surface mining, are affected by the size and the amount of the deposit.

Initial exploration is performed by taking cores on a wide sapcing. This is used to define the extent of the reserve and to get an initial handle on the interrelationships of the geological factors from one end of the coal prospect to the other. This exploration program is used to establish the overall broad exploration phase where the coal thickness, the minable reserves, and the general coal quality parameters are determined. It is in this broad exploration phase that the initial determination of whether it is a thermal coal or a metallurgical coal is defined and established. In the next stage of exploration closer correlations are obtained of the coal and the coal seam characteristics from one side of the project to the other. These correlations are used to determine the mining method and the overall mine design for the coal project. Geological exploration will detail the conditions in and around the coal reserve and the coal body. Details of the conditions help delineate the mining method that is to be chosen. The exploration program can also tell if there are any specific geotechnical problems, such as faults, bad roof conditions, or soft floor that can adversely affect mining and the mining method. If these geotechnical problems can be delineated early enough the mining plan and mining methods can be so chosen to minimize their effect on the coal produced from the mine.

The exploration program also affects the coal preparation directly in four areas: 1) the general type of exploration program undertaken, 2) the type of samples that are taken during the program, 3) the quantity of the samples and 4) the type of coal analysis run on the samples.

When the exploration program is conducted on a limited budget, a few small diameter core holes are used for the overall reserve predictions and quality assessments; this can seriously effect the net cost to the preparation plant because many assumptions must be made in projecting the available data to bulk and as-mined coal. When existing mines are located nearby with similar mining equipment and by system and data can be taken directly from those mines the effect of a minimum exploration program can be minimized.

A detailed exploration program can often discover new and unusual factors that would otherwise not be expected. From a coal preparation point of view, it is best to have actual coal taken from adit or test pits by machinery that is similar in nature to the actual mine equipment that will be used. While this is often not available, it is best to get core holes of large diameter, at least as large, if not larger than the size that is expected to be fed to the coal preparation plant. Using 2-inch-diameter cores for projecting the size distribution and quality to be received at a coal preparation plant with an expected top size feed of 6 inches can be very misleading and can bias the sizing of the various circuitry in the plant. The end result in coal quality to be shipped can be directly related to the amount of planning and thought that goes into the exploration program, the mine design and the mine planning prior to designing the coal preparation facilities.

THE IMPACT OF MINING METHODS ON COAL PREPARATION PLANT DESIGN

There are two basic types of coal mining: underground and surface. In underground mining there are three different types presently practiced in the coal industry. The three underground mining methods are conventional mining, continuous mining, and hydraulic mining. Conventional mining separates the mining operation into drilling the coal, loading explosives, shooting, and then loading out the coal for transport. Conventional mining produces the coarsest coal of all underground methods, as there is very little cutting or grinding of the coal. Continuous mining is total cutting of the coal in one operation. Continuous mining falls under two general groupings: 1) where continuous mining machines use the room-and-pillar method common in the conventional mining scheme and 2) where longwall or shortwall configurations are used. Hydraulic mining, which is just now beginning to be utilized in the United States, makes use of a high pressure jet of water to mine and sluice the coal from the face.

Surface mining can be the most selective of all the mining methods and also produces the coarsest coal of all mining methods with minimal amount of fine material compared to underground mining, and in fact surface mining can often times produce a high enough quality coal that it can be shipped direct. As mechanization in the coal industry has proceeded to give remarkable improvements in productivity, at the same time disadvantages have appeared that offset some of these gains. Large-volume continuous miners lose some of their advantages with interions or delays in an attempt to improve coal quality and, therefore, selective underground mining has been largely abandoned. Also, since continuous mining produces a finer product and more water is required for dust abatement, a much greater burden is placed on the preparation facilities.

Various studies have indicated there is a definite difference in the size consist of coal produced by various miner types and also between continuous and conventional methods. Coal preparation is often required with underground mining because, usually some amount of roof and floor material must be taken to give adequate height for the mining equipment, as the coal seam pitches and rolls, and thickens and thins. Underground mining also has a tendency to be less selective when it comes to delineating the coal and roof and the coal and floor interface. Underground mining normally takes all material that is included within the coal seam, even when this parting can reach a foot or more in thickness. Surface mining can exclude partings greater than 6" in thickness.

A study by the U.S. Bureau of Mines in 1973 indicated that conventional and continuous mining for the same seam of coal exhibited different size and washability characteristics. The size distribution for the conventional mined coal was coarser than the coal from the continuous mining, and at the same time the continuous mined coal was more uniform in size content from top size to bottom size. Differences in size consist were more prominent in the coarser size range than in the finer range. This data is shown in Table II and graphically repre-ented on Figure 1.

The mining systems significantly effected the amount of ash and sulfur in the raw coal, with continuously mined coal having more of each (Table III). The excess of ash was due to a loss of cutting horizon, and increased sulfur was caused by the high sulfur extraneous roof and floor material. Ash and sulfur was influenced by size, both decreasing with the fine coal in both systems. This was primarily due to liberation of the pyrite sulfur constituents. Washability characteristics of coal from the two mining seams varied and were primarily influenced by size. The conventional mined samples required a lower cleaning gravity, approximately 1.5 specific gravity units, while a higher gravity of approximately 1.53 was necessary for the continuous mined samples. Yields at each separating gravity were higher and more consistent in conventional mined coal. Considering the amount of near gravity material, conventionally mined coal was easier to clean at a lower gravity than the continuous mined coal was at a higher gravity. Results of the study indicated that conventional mining, due to its more inherent selectivity, when mining a particular seam of coal allowed for a more uniform and cleaner raw coal product and a higher yield and a higher clean coal quality than the same from continuous mining operation. Unfortunately, numbers to verify the comparative productivity from each seam was not available in this study.

Other experience by Kaiser Engineers has dealt with comparing surface mining, and underground continuous and hydraulic mining of the same seam of coal in western Canada. From this Canadian operation the introduction of surface mined coal, underground continuous mined coal, and underground hydraulic mined coal into a common preparation plant has caused some unique problems. The following section compares the impact of these three coals on the same plant. The data is shown in Table IV and graphically on Figure 2. It should be noted that due to the softness of western Canadian coals this coal is much finer than that shown above.

IMPACT OF RAW COAL CHARACTERISTICS ON COAL PREPARATION PLANT DESIGN

Surface Moisture

One of the characteristics that is most often ignored in raw coal quality - and it can have a most serious impact in the initial stages of a coal preparation facility - is the moisture of the raw coal. If the coal moisture is high, as for example with the hydraulically mined coal, this will give exceedingly difficult handling problems particularly if the weather conditions cause extremes in temperature. High moisture, particularly surface moisture content, will cause freezing in storage facilities whether open stockpiles, enclosed silos, or bunkers. These extremes in high surface moisture can cause the coal to become one large mass that in some extremes has required operators to drill and blast the coal in the stock piles to allow it to flow freely into the reclaim system. This high moisture content can also cause a unique situation where more water is coming into the plant on the raw coal than is going out on the clean coal. This could cause the plant to have an excess of water to dispose of, particularly when water may not be recirculated through the plant, because fresh water is normally required for pump gland water and/or sealed water on vacuum pumps. This internally made water will be consistently higher in solids content than can be normally used. High moisture content can also cause problems in good weather - i.e., warmer weather - when it can cause sticking and/or other handling problems in the storage facility, giving improper drawdown and other material handling problems.

Size Consist

The size consist of the raw coal coming into the plant causes several different problems. To produce the same top size feed to a preparation plant the material from a surface mine or a conventional mine must be crushed or broken finer than the same material from a continuous or hydraulic mine operation. This entails larger and more extensive breaking and crushing equipment inasmuch as that the communition equipment is sized upon the amount of material that must be reduced from the total top size to the final product size. Once the material has entered the plant, the difference in size consist is found in differences in the size and quantities of equipment and in the volumes of material that are handled in the circuits of the plant. A typical plant has three circuits; Circuit 1 is for coarse material, Circuit 2 for the intermediate site material, and Circuit 3 for the fine material. Let us now look at three different size distributions of feed to this typical plant and the effective size of the circuitry involved. These different size distributions are shown in Table IV and graphically in Figure 2. One is representative of a surface mine, the second of an underground continuous mine and the third of an underground hydraulic mine. Each of the three circuits is sized to handle the same size ranges of material. From Table II the various circuitry must handle different percentages in each size depending on the source. For comparison we will use continuously mined coal as a reference. The same circuitry handling surface mined coal will require in the coarse coal circuit 11% increase over the continuous mined coal and the hydraulically mined coal will require a 3% decrease. These variations in size distribution cause different amounts of equipment necessary in each of the circuits. When a plant must be designed as in the case of the Canadian operation, to handle all three types of material, it must be sized for maximum percents from each of the three types of coal mined. This allows for a very wide swing in the size distribution and a corresponding amount of material processed at any particular time by any particular circuit.

Coal Quality

Table IV also shows for the same three size distributions of coal the differences in raw coal quality for each of the three materials. Based on this the same plant, to produce the same expected final raw coal quality will have very different yields depending on the material fed. This requires that the circuits must be designed to handle wide yield variations.

Dedending on the type of mining method that is used, very different coal preparation plants are required. If the mining method is not known when the coal preparation plant is being designed, the plant must be designed to handle the variations similar to those shown above. This variation can cause a greater capital expenditure than would be otherwise expected if the mining method was determined when the coal preparation plant was being designed.

CONCLUSION

Coal preparation really begins when the first core hole is sunk to determine the coal reserve. From this point, when proper planning is utilized to develope the most economic mining method and this is considered and carried forth into the coal preparation plant design, the optimal coal quality characteristics can be obtained at the maximum yield. Geological and mining engineers should consider in their planning, exactly what effect any decision made in designing an exploration program or in planning and laying out a mine will have on the overall coal quality.

REFERENCES

Stefanko, R., I.K. Chopra, R.V. Ramani, "Mining Influence on Site Consist and Washability Characteristics of Coal", Society of Mining Engineers Fall Meeting, September 22-25, 1974

Table I

Factors in the Choice of a Mining Method

<u>Physical</u>	
Geometry	Size, shaps, continuity, and depth of the orebody or group of orebodies to be mined together Range and pattern of coal quality parameter
Geology	Physical characteristics of coal overburden and soil Structural conditions Hydrologic conditions
Geography	Topography Climate
<u>Technologic</u>	
Safety	Identification of hazards
Human resources	Availability of skilled labor
Flexibility	Selectivity in product and tonnage
Experimental aspects	Existing or new technology
Time aspects	Requirements for keeping various workings open during mining
Energy	Availability of electric power
Water requirements	
Surface area requirements and current use	
Environment	Means of protecting the surface, water resources, and other mineral resources
<u>Economic</u>	
Cost limits	
Optimum life of mine	

Table IV

Comparative Size Distribution and Coal Quality Depending on Mining Method
(From a Canadian Coal Mining Complex)

Surface Mine

Size Fraction	Feed Surface Moisture % by weight	Feed Weight	Feed Ash	Product Yield	Product Ash
1-1/2" x 28 M		69.0	20.3	70	9.4
28 M x 60 M		12.0	12.9	80	6.1
60 M x 0		19.0	12.8	90	8.1
TOTAL	6.0	100.0	18.0	75	8.7

Underground Continuous Mine

Size Factor	Feed Surface Moisture % by weight	Feed Weight	Feed Ash	Product Yield	Product Ash
1-1/2" x 28 M		62.0	22.8	67.0	9.4
28 M x 60 M		15.5	14.8	80	6.1
60 M x 0		22.5	13.9	90	8.1
TOTAL	8.0	100.0	19.6	74	8.5

Underground Hydraulic Mine

Size Fraction	Feed Surface Moisture % by weight	Feed Weight	Feed Ash	Product Yield	Product Ash
1-1/2" x 28 M		60.0	23.6	65.0	9.4
28 M x 60 M		16.0	15.0	80	6.1
60 m x 0		24.0	14.0	90	8.1
TOTAL	12.0	100.0	20.0	73	8.5

Table II

Comparative Size Distribution
(From Continuous and Conventional Mining Sections)

Size Fraction	Continuous* % weight	Continuous* Cum % weight	Conventional* % weight	Conventional* Cum % weight
+2"	7.0	7.0	25.0	29.0
2" x 1/2"	38.0	45.0	35.0	60.0
1/2" x 1/4"	20.0	69.0	14.0	74.0
1/4" x 1/8"	17.5	82.5	13.0	87.0
1/8" x 28 M	12.0	99.5	8.2	95.2
28 M x 0	5.5	100.0	4.8	100.0
TOTAL	100.0		100.0	

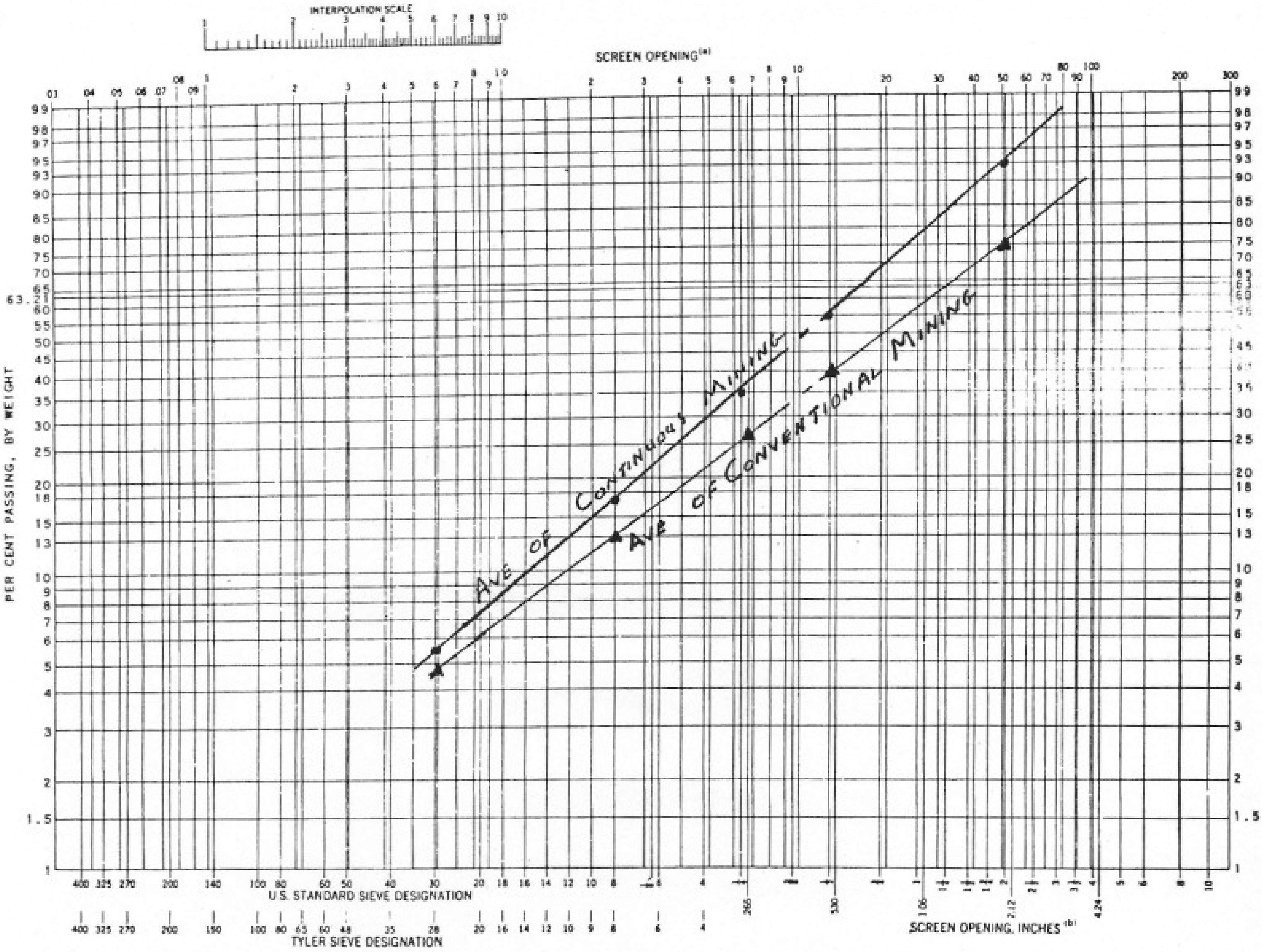
* Average of (4) four samples

Table III

Comparison of Cleaning Characteristics
(From Continuous and Conventional Mining Sections)

Factors Studied - Mining Systems	Continuous Mining	Conventional Mining
Percentage of ±0.10 Specific Gravity Material & Ease of Cleaning	13.47 Difficult	10.68 Nearly moderately difficult
Float Weight or Yield Percent	70.82	84.04
Float or Yield Ash Percent	6.92	6.61
Float or Yield Sulfur Percent	3.89	3.56
Sink Weight Percent	29.18	15.96
Sink Ash Percent	68.83	56.14
Sink Sulfur Percent	6.81	9.47

Source for Table II & III:
"Mining Influence on Site Consist and Washability Characteristics of Coal"



(A) Any scale. If in millimeters, coincides with lower scale.

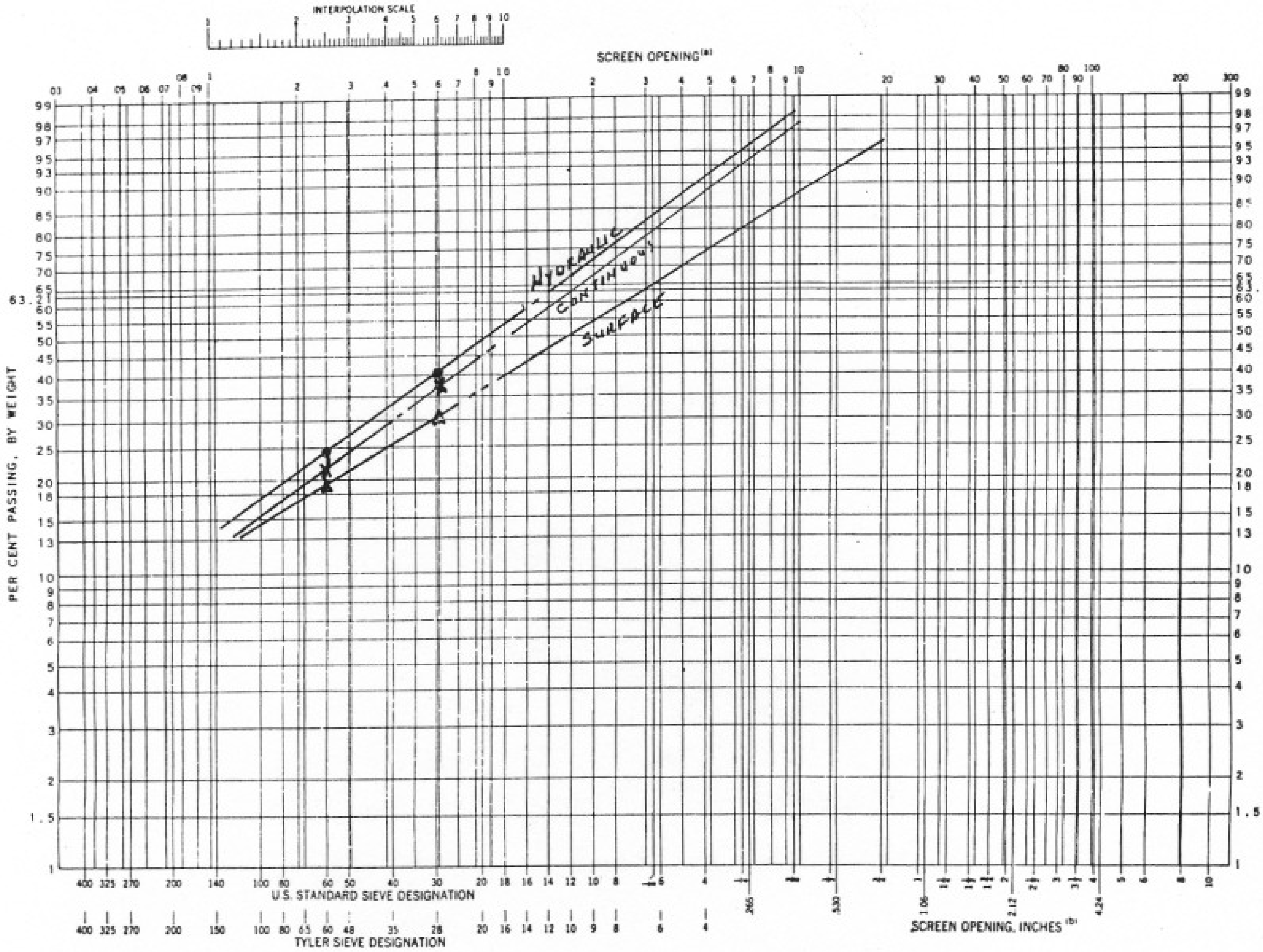
(B) Square hole if used as continuation of fine series.

GRAPHICAL FORM FOR REPRESENTING DISTRIBUTION OF SIZES OF BROKEN COAL

(From: Landers, W.S., and Reid, W.T., A Graphical Form for Applying the Rosin and Rammler Equation to the Size Distribution of Broken Coal: Bureau of Mines Inf. Circular 7346, 1946.)

AVERAGE PARTICLE SIZE (INTERSECTION OF SIZE DISTRIBUTION LINE WITH 63.21% PASSING LINE)	$\bar{X}$	
SLOPE OF SIZE DISTRIBUTION LINE (TANGENT OF ANGLE)	N	

Comparative Size Distribution for Continuous and Conventional Mining Sections - Figure 1



(A) ANY SCALE. IF IN MILLIMETERS, COINCIDES WITH LOWER SCALE.

(B) SQUARE HOLE IF USED AS CONTINUATION OF FINE SERIES.

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AVERAGE PARTICLE SIZE (INTERSECTION OF SIZE DISTRIBUTION LINE WITH 63.21% PASSING LINE)	$\bar{X}$	
SLOPE OF SIZE DISTRIBUTION LINE (TANGENT OF ANGLE)	N	

Comparative Size Distribution for a Canadian Coal Mining Complex - Figure 2