OTISCA T-PROCESS: A NEW BENEFICATION APPROACH FOR THE PREPARATION OF COAL SLURRIES

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Abstract

Coal preparation by gravitational separation methods rarely provides a product coal with a practical yield that has less than three weight percent ash. The Otisca T-Process provides an alternate physical preparation method that consistently provides less than 1.5 weight percent ash product coal at a BTU yield in excess of 95 percent from common steam coals such as the Pittsburgh seam. Furthermore, the product coal from this process has a particle size distribution below 30µm. The discussion will involve some of the subtleties of the process, analytical results and utilization expectations.

LIMITATIONS OF CONVENTIONAL GRAVITY SEPARATION METHODS

In the consideration of the preparation of a coal feed stock for the production of coal-water slurries, one is immediately faced with the fact that generalizations about either coal or the coal products from various beneficiation schemes are inevitably inaccurate due to the broad variations of coal chemistry, mineral distribution and morphology that occur from coal seam to seam and even throughout a particular seam. For example, the raw coal from the Pittsburgh seam that underlies a large fraction of southwestern Pennsylvania, northwestern West Virginia and eastern Ohio varies in volatile matter from 30-40 wt.%; in ash from 6-22 wt.% and in total sulfur from 1-4 wt.%[1]. By limiting our overview to Washington County, Pennsylvania, the seam chemistry variations tend to narrow within tolerable limits, i.e., volatile matter 38 ± 2 wt.%; ash 11 ± 5 wt.%, and total sulfur 2 ± 0.5 wt.%. Through investigations by the U. S. Bureau of Mines[2] and others[3], we are afforded some data relative to the cleanability of this coal. Even in coal preparation, generalities abound, e.g., the finer the size distribution of the raw coal, the greater the reduction of impurities in the product coal; and the lower the specific gravity of the separating medium, the greater the reduction in impurities in the product coal. The details that tend to support these arguments are shown in Figures 1 and 2 for three different samples of Washington County, Pittsburgh seam coal cleaned under

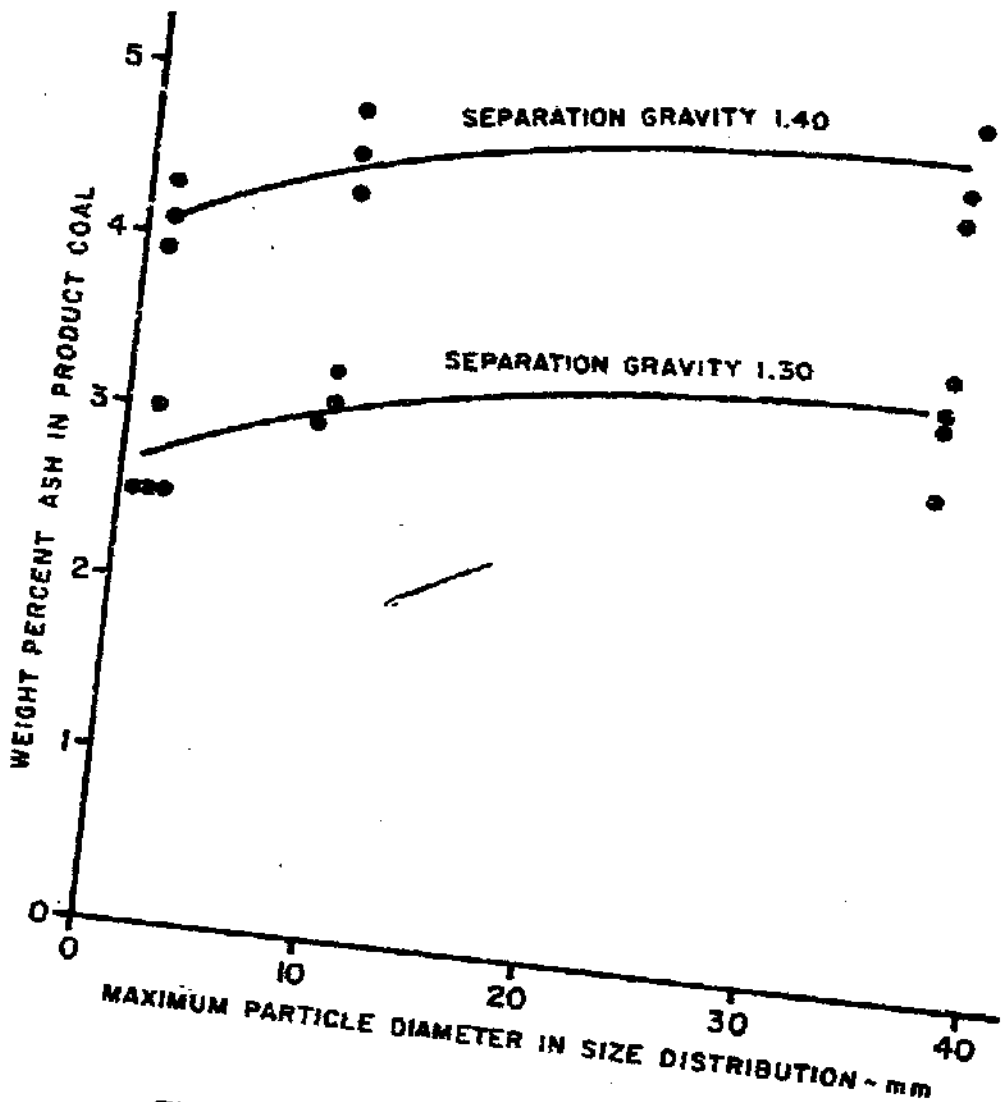


FIGURE 1: Three Pittsburgh Seam Samples From Washington County, Pennsylvania Separated By Gravity Methods

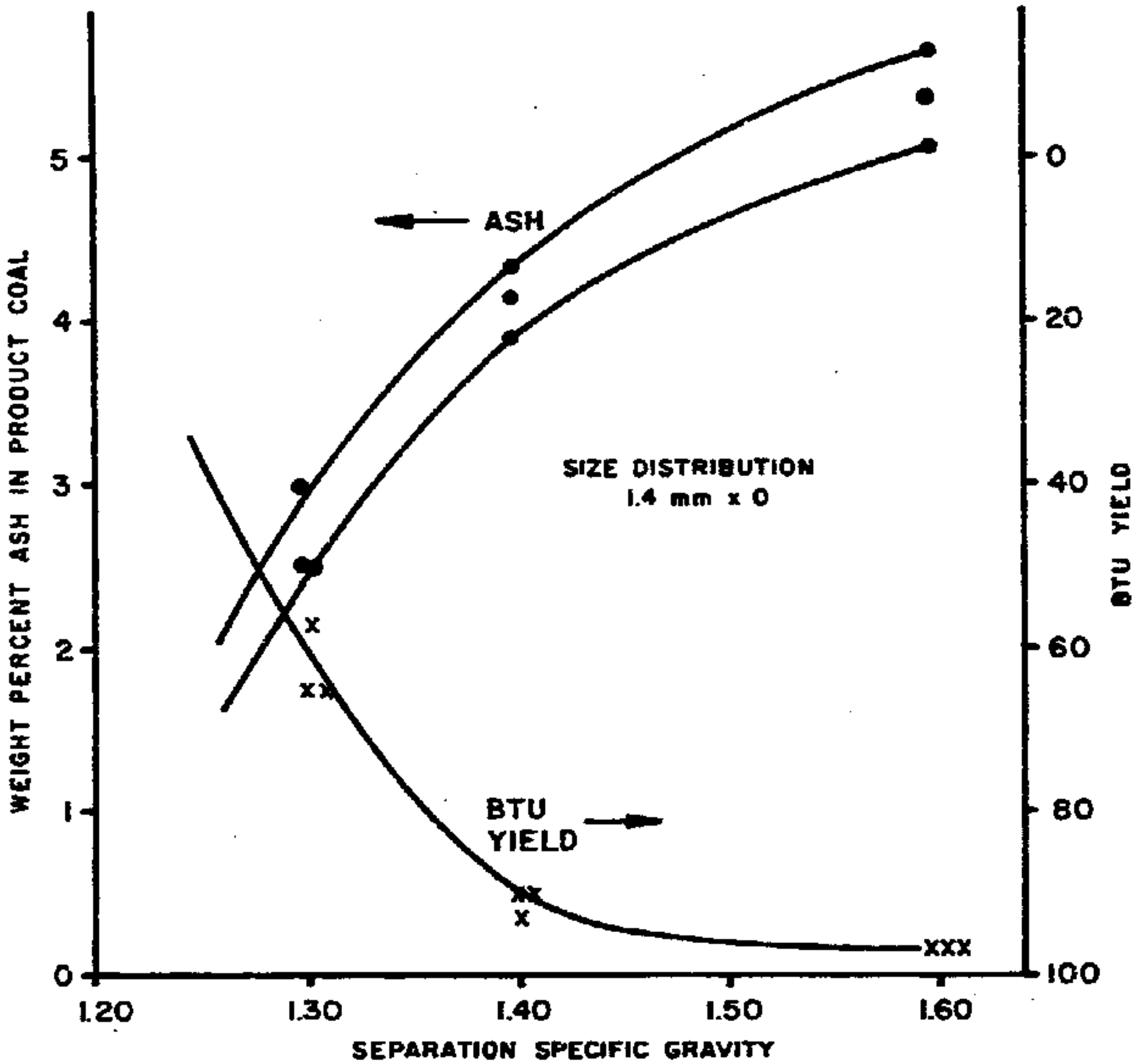


FIGURE 2: Three Pittsburgh Coal Seam Samples From Washington County, PA. - Density Effect Separated by Gravity Methods

laboratory conditions by conventional gravity separation methods.

In the first instance there appears to be a dramatic improvement in coal purity when the parting liquid specific gravity is reduced from 1.40 to 1.30. On the other hand, the reduction in particle size distribution from 1½ inch (38mm) to 1.4mm does not afford much advantage in improved product coal. A naive prediction from Figure 1 might allow one to cite that the inherent (i.e., chemically bound) mineral matter in a Pittsburgh coal was in the range of 2%. Figure 2 might support this form of insight; however, the plot also presents a second limitation of gravity separation; that is, as the specific gravity of the parting liquid decreases, so too does the BTU yield of the product coal. Such a behavior depletes the economics of very deep cleaning to produce a very low ash product unless a suitable market is developed for the less pure product.

The conclusions of this brief overview are similar to those that might be developed for many seams throughout the coal industry. Since the goal has been to produce a cleaner product coal, the natural direction has been to focus on better separation procedures for finer coal sizes. In the pursuit of these goals, and with the application of simple gravity separation methods, one is forced into a natural barrier which establishes a limit of cleanability. The driving force for gravity separation can be considered as the product of the gravitational force constant times the particle diameter squared times the density differential between the separating particle and the parting liquid according to Stokes' Law. The barrier is developed by thermal or particle turbulances that occur in the parting liquid which tend to prevent particles with diameters smaller than 20μm (micrometers) from separation in any reasonable time. A recent, detailed investigation[4] of the separation of identical samples of a 28 mesh x 0, 100 mesh x 0 and a 200 mesh x 0 coal under ideal conditions demonstrated that the product coal ash content <u>increased</u> throughout this series. Furthermore, the concentration of the middling (neither sink nor float) fraction also increased. The middling fraction was identified as unseparable raw coal with a particle size distribution below 25μm. An examination of a Rosin-Rammler plot, as illustrated in Figure 3, explains the barrier in a straightforward manner. If we accept the observation that particles with a diameter of less than 20um will not separate in a reasonable time limit, e.g., fifteen minutes, then that fraction of raw coal will be distributed throughout the entire liquid phase at the end of a normal separation. The larger sizes will report to either the float or sink fraction as Stokes' Law directs. From the data shown in Figure 3, this suggests that the unseparated coal in the liquid phase in a 28m x 0 separation is about 10 wt.%; that in the 100m x 0 it is about 25 wt.%; and that in the 200m x 0 it is about 55 wt.%. Clearly, the unseparated raw coal is contributing excess ash content to the product coal, coal to the refuse, and an increase in middling content. A quantitative analysis for this particular coal related the model to the corresponding observations, thus rendering further investigation unnecessary.

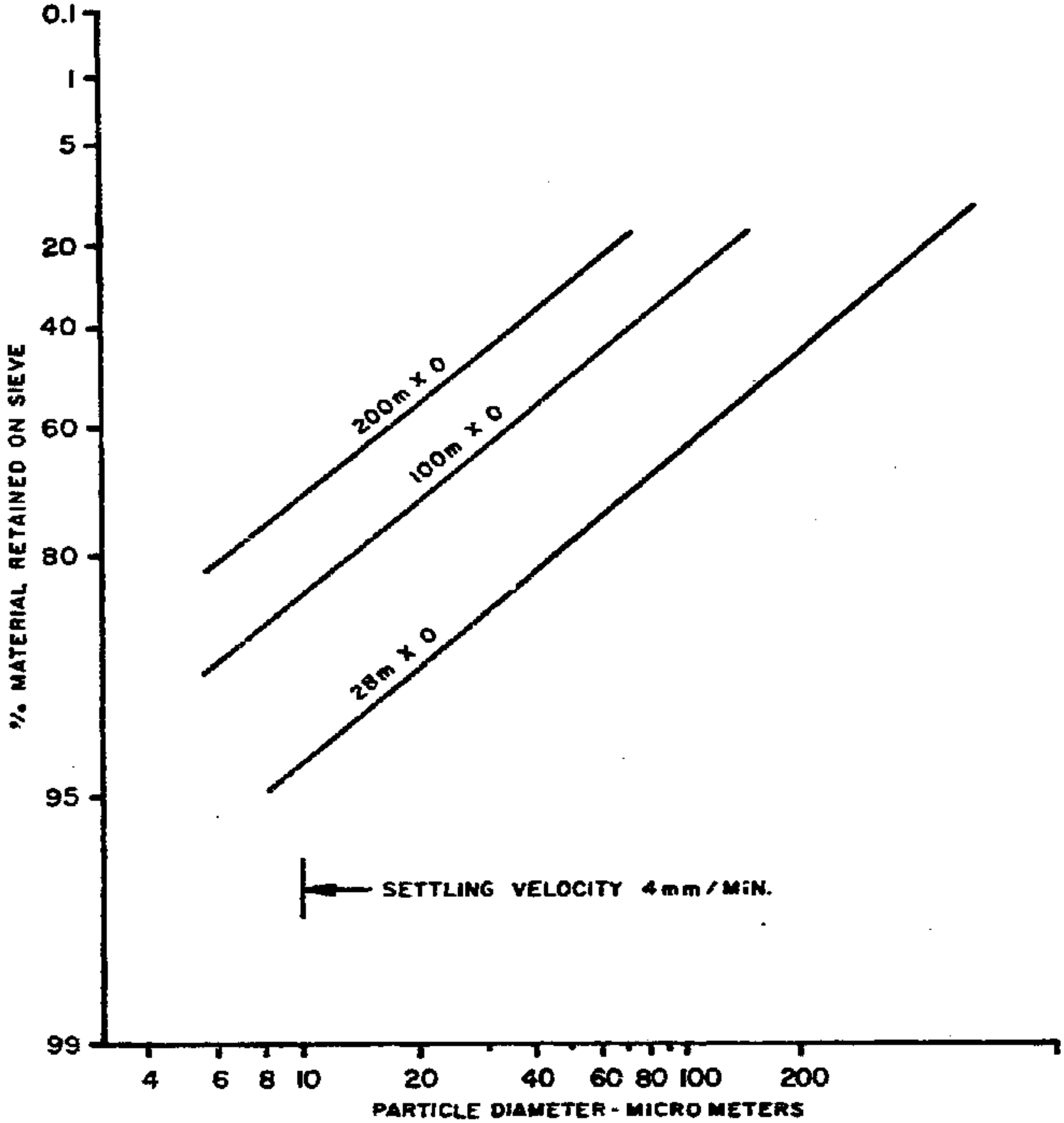


FIGURE 3: Typical Rosin-Rammler Plots For Fine Coal Samples

The obvious maneuver around the barrier is to increase the value of the gravity constant by the application of a centrifuge or cyclone. Through the support of the Department of Energy[5], Otisca undertook the separation of fine raw coal down to and including 400m x 0 size distributions utilizing a dense liquid cyclone. The results, although very preliminary, do bear out the model that was established above, as the separations are very sharp even for 400m x 0 fractions, as is illustrated in Figures 4 and 5. The Tromp curves for a 28m x 0 separation as shown in Figure 4, and the 400m x 0 fraction shown in Figure 5 for an Upper Freeport coal, illustrate that by strongly increasing the gravity term through cyclonic action, clean separations can be effected. Interestingly enough, the separation of a full 400m x 0 was achieved; however, the Tromp curve and complete analysis will not be available until later this fall.

THE OTISCA T-PROCESS

During the investigation of the various procedures for gravity separation of coal, Otisca developed a rather simple procedure for the determination of the pure mineral matter content released during size reduction. The procedure involved a simple agglomeration of the carbonaceous material from a water slurry using one of the fluorochlorocarbons. Once the specificity of this procedure was recognized, it was only a natural step to ask the question, "What is the lowest limit of mineral matter separation from a raw coal by physical means?" The answer has not been achieved even after five or so years of intensive study; however, what has been observed supports our comment that generalities regarding coal are still invalid and that some coals can be deashed below 0.3 wt.% ash.

The Otisca T-Process consists of three steps: raw coal particle size reduction into the range of 15μm x 0, the agglomeration-separation of the product coal from the mineral matter which remains dispersed in the water phase, and the complete recovery of the chlorofluorocarbon agglomerant for recycling in the process. The product coal is recovered at nearly 100% BTU recovery and leaves the plant with less than 1 wt.% ash and 100 parts per million agglomerant. The moisture content of the product can be varied from less than 8 wt.% to over 30 wt.% depending on whether or not a dry powder or coal-water slurry is desired. A two hundred pound per hour pilot plant is now in start-up as supported by Fuel Supply Service, Inc., a subsidiary of Florida Power and Light Company of Miami.

Rather than examining the intricacies of the various mechanisms of this separation process or its applicability over the twenty or so seams that have been investigated to date, it would seem more appropriate to look at its application to the Pittsburgh seam coal where some background has been established, and then consider some of the implications of these results.

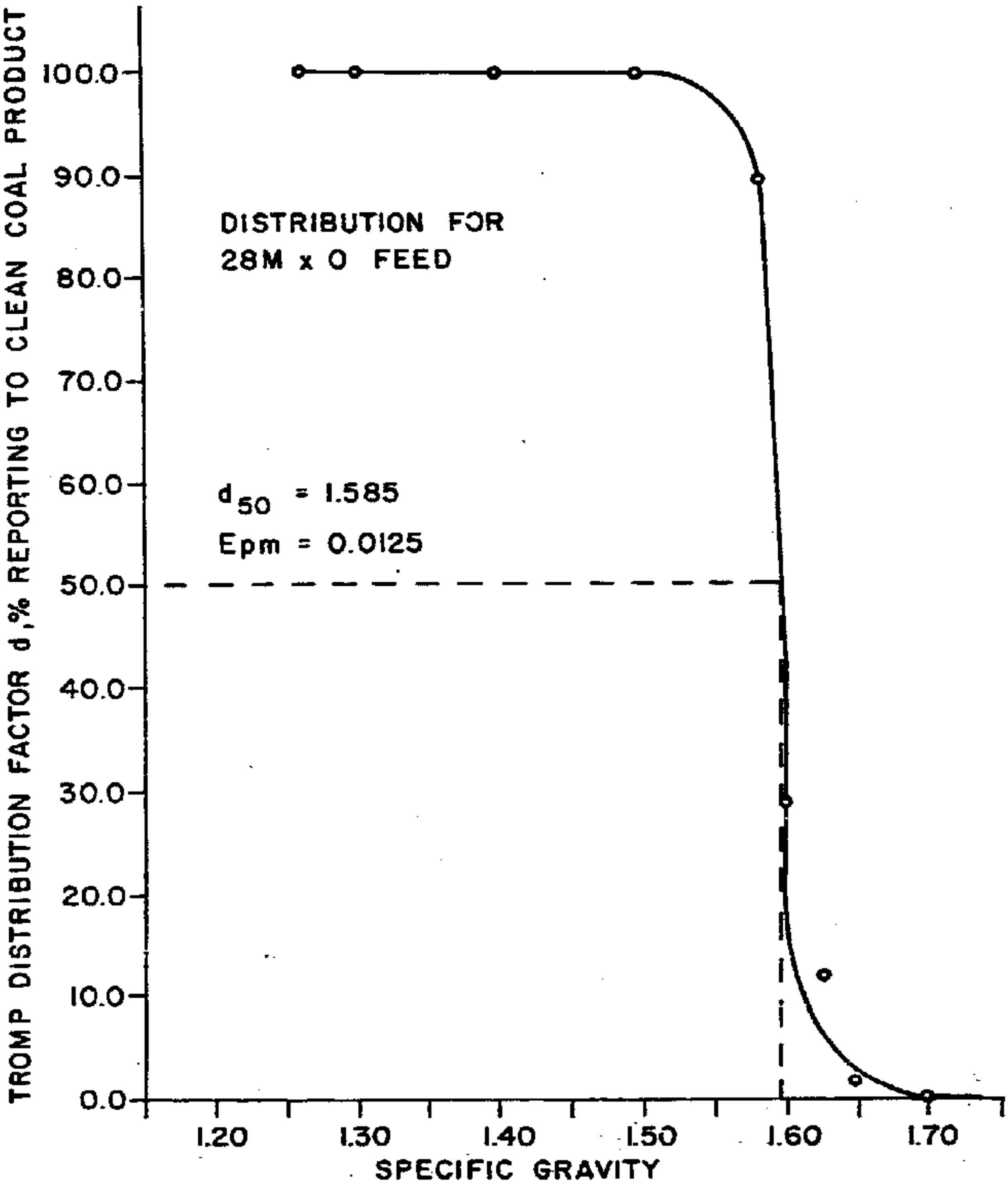
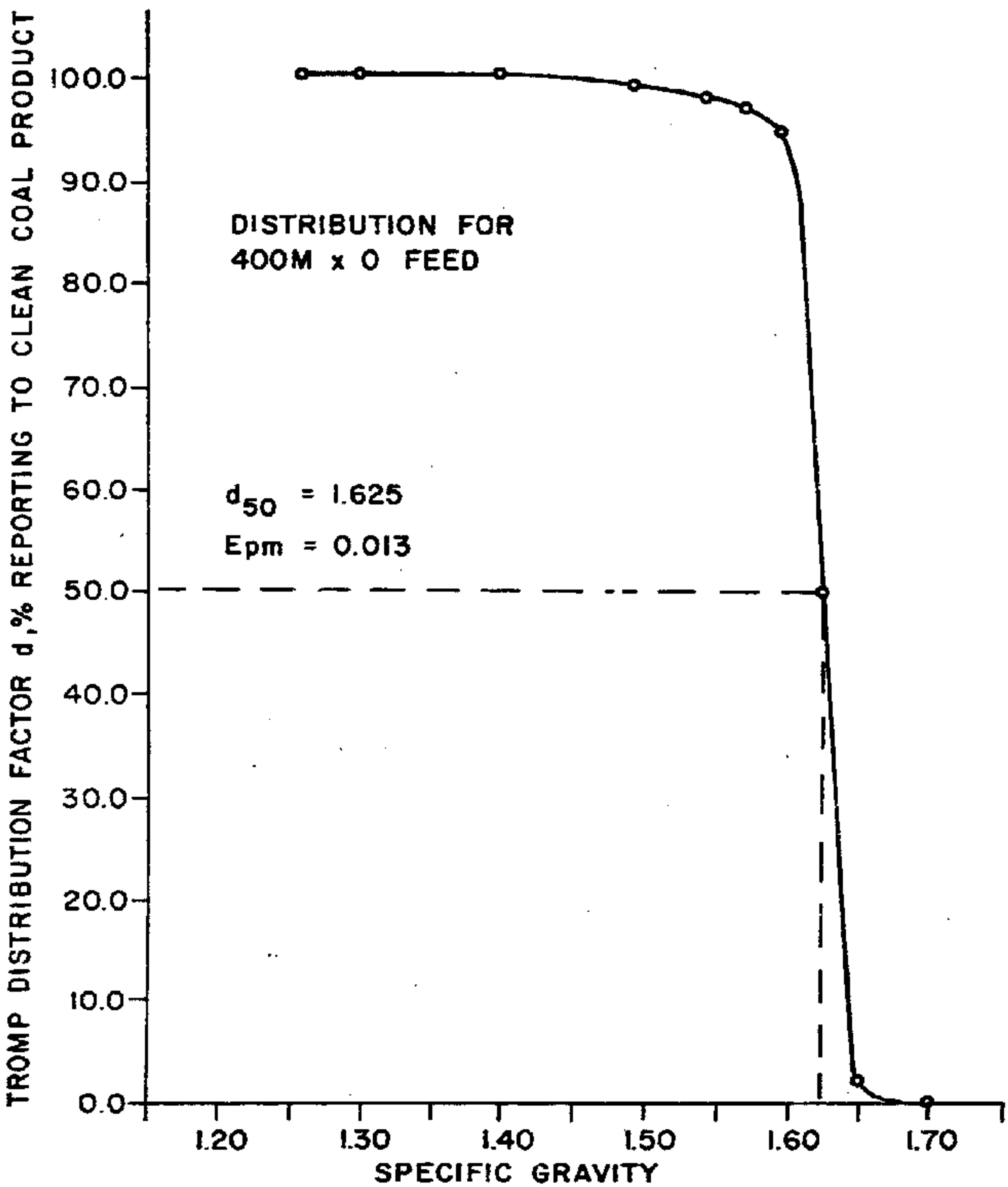


FIGURE 4: Heavy Liquid Cyclone Separation Of An Upper Freeport Coal



<u>FIGURE 5</u>: Heavy Liquid Cyclone Separation Of An Upper Freeport Coal

A two pound sample of Otisca T-coal was prepared following our standard procedures and submitted with a sample of the parent coal (Pittsburgh seam washed coal from Bethlehem Steel Mine, Marianna No. 58, Washington County, Pennsylvania) to the Department of Energy Research Center at Morgantown, West Virginia for analysis. A particle size distribution of the product coal was conducted using a Micromeretics Sedigraph 5500L that resulted in a distribution as shown in Table 1.

Table 1
Size Distribution of a Pittsburgh
Otisca T-Coal

Apparent Spherical Diameter-Micrometers	Cumulative Mass Percent Finer Than
5.7	100
4.0	91
2.8	69
2.0	47
1.4	29
1.0	17

The chemical analyses of the raw and product coals are provided in Table 2 and the chemical analyses of the ash products from a low temperature ashing procedure of the coals are provided in Table 3. The heat value of the product coal was in the range of 15,200 BTU/lb.

Table 2
Coal Analyses From Pittsburgh Seam

	Otisca-T Feed Coal	Otisca-T Product Coal
Carbon	80.54 wt.%	81.76 wt.%
Hydrogen	6.33	6.66
Nitrogen	1.57	1.71
Sulfur	1.18	0.83
Ash	5.51	0.62
Oxygen (by difference)	2.14	8.42
Moisture	2.73	0.0
Volatiles	36.65	40.31

Table 3
Ash Analyses From Pittsburgh Seam Coal
(in weight percent)

	Otisca-T Feed Coal		Otisca-T Product Coal	
	in ash	in coal	in ash	in coal
CaO	2.83	0.1559	7.99	0.05
K_2O	1.41	0.0777	1.33	0.008
P_2O_5	0.26	0.0143	0.91	0.006
SiO_2	49.67	2.7368	31.28	0.194
Al_2O_3	25.30	1.3940	20.79	0.129
Fe_2O_3	12.48	0.6876	13.01	0.081
TiO_2	1.22	0.0672	6.13	0.038
MgO	0.78	0.0430	2.79	0.017
SO_3	2.37	0.1306	4.78	0.030
Na_2O	0.56	0.0309	<0.20	0.001
SrO			0.46	0.003
PbO			0.99	0.006
As_2O_3			0.11	0.0007
NiO			0.23	0.0014
Cr_2O_3			0.14	0.0009
Ag			Trace	
HTA Fusion Temp. (°F)	2600		2300	

A comparison of the classical preparation data of the Pittsburgh coal with that of the T-Process shows that one can readily conclude that if the separation process is specific, particle size reduction does liberate more ash provided that the correct procedures are utilized for size reduction. The fact that more mineral matter release can be achieved is supported by an examination of the particle size distribution of the mineral matter product of a low temperature ashing procedure on massive coal since it does indicate that 1-2 wt.% ash exists in a particle size range below 30μm. Clearly, this is coal specific and will vary from coal to coal. Therefore, for the eventual production of a low ash product, one must achieve mineral matter-coal fracture in the particle size ranges below 30μm. With some coals this is a very difficult task; but again, all of the specifics at this point in time are not clearly understood.

After a careful investigation of the procedures currently available in the market place, to produce 15μm x 0 raw coal slurries that would lead to a T-coal product, Otisca designed its own model of a rather unique stirred ball mill.

That device is producing a 90% 15μm x 0 coal slurry from a 60m x 0 Pittsburgh seam raw coal at a continuous rate of 200 pounds per hour for an estimated energy input of under 40 kwh/ton.

The separation process reduced the ash in the raw Pittsburgh coal about 90% and an examination of the reduction based on specific elements indicates that potassium, silicon, aluminum, iron and sodium were also decreased at a similar rate. The alkaline earth elements and phosphorous were eliminated at a somewhat reduced rate of about 60%, while only 43% of the titanium was eliminated. Pyritic sulfur has been all but eliminated. Clearly, all of these observations represent only one data point, i.e., one separation sequence with one size distribution. Hence, much more work is at hand to understand and optimize the release of the retained minerals. This work is currently in progress as it appears quite reasonable to assume that a reasonable number of coals can be deashed by this process to at least 0.3 wt.% ash.

The Otisca T-coal has also been examined as a coal-water slurry with solid contents exceeding 60 wt.%. Additives under 1 wt.% allow slurry viscosities under 300 cp without disruption of the ash content.

Commercialization of the Otisca T-Process is well underway. A one ton per day pilot plant consisting of five stages: milling, agglomeration, coal separation, water recovery and agglomerant recovery is in start-up. The milling circuit as previously indicated is on-line.

Agglomeration and separation of the product coal can be achieved by several approaches. Initial testing involves a circuit which includes a high shear mixer that mixes the agglomerant with the coal-refuse water slurry to produce large, stable coal agglomerates. Then the coal agglomerates are seperated from the water-mineral dispersion in a drum separator. A sieve bend could be an alternate separator. Also, a cyclone agglomerator/separator has also been successfully demonstrated under batch conditions at a separation rate of 1,100 lbs/hour, producing a coal of 0.3 wt.% ash content. The mixer and drum separator are on-line. The mineral matter-water slurry is transported to a thickener that allows for water clarification and recycle.

The product coal agglomerates proceed to the evaporators which evaporate the agglomerant leaving a product coal with 10-40 wt.% moisture as desired and 100 parts per million of retained agglomerant. The vaporized agglomerant is condensed for reuse. The evaporators and recovery units are installed and are in the early stages of start-up.

The three near term goals of the pilot plant are:

1) Operate with a Pittsburgh seam coal to demonstrate continuous operation and viability of first generation unit processes;

2) Substantiate the preliminary economic analysis; and

3) Produce sufficient product coal for downstream studies related to storage, transport, and combustion.

The completion of these tasks, which is anticipated early this fall, will allow the plant to be used for the investigation of a variety of coals and further unit process optimization.

A preliminary economic analysis suggests that capital costs will be in the range of $70,000 per ton-hour and operating costs plus capital recovery are in the range of $0.60 per million BTU.

In conclusion, evidence has been provided that coal can be physically cleaned to ash contents below 0.6 wt.% and this identifies a new fuel. The next major goal is to consistently and commercially produce this new fuel with ash contents below 1 wt.% from available raw coals.

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