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**Blending Crushed Coal by Recycling  
Through a Bin Equipped  
With a Particle Distributor**



UNITED STATES DEPARTMENT OF THE INTERIOR

**Report of Investigations 7646**

# **Blending Crushed Coal by Recycling Through a Bin Equipped With a Particle Distributor**

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# BLENDING CRUSHED COAL BY RECYCLING THROUGH A BIN EQUIPPED WITH A PARTICLE DISTRIBUTOR

by

James L. Konchesky<sup>1</sup>

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## ABSTRACT

Crushed coal, consisting of a wide range of sizes, was effectively blended by recycling it through a bin equipped with a particle distributor. Vertical blending was accomplished by simply recycling the coal; it was not significantly influenced by the horizontal blending that was achieved by the distributor. The method was effective, even though the coal was wet and possessed poor flowing characteristics. Recirculation appears capable of providing uniform blends of solids that can be more efficiently processed. Recirculation also appears useful, preceding packaging operations, to insure for blending of solids into specification products. Continuous measurement of the bulk density of the coal by a gamma ray meter proved to be an effective monitor of vertical blending effectiveness.

## INTRODUCTION

Solids stored in bins can segregate, both horizontally and vertically. Horizontal segregation often is caused by differences in physical properties of the particles, such as size, density, and shape. A typical example is "cone tumbling," the formation of a cone-shaped pile of solids that are being centrally loaded into a bin. The larger, heavier particles have a greater momentum and the smoother particles slide better, with the result that such particles move farther down the sloping surface of the pile and accumulate near the wall of the bin. The smaller, lighter, and rougher particles tend to accumulate in the center of the pile. Horizontal segregation of particles by cone tumbling during barge and railroad loading can result in vertical segregation when the particles are transferred to a bin. Vertical segregation can also occur when a bin is charged with successive batches of solids having dissimilar or variable chemical and physical properties.

Horizontal segregation from cone tumbling can be minimized by making the particles very small or the size range narrow, although product specifications and process economics may not permit these solutions. Horizontal segregation can also be minimized by distributing or spreading the solids uniformly across the bin to produce a relatively smooth bed instead of a pile. In many cases,

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horizontally segregated solids are no problem since they can be reblended as they discharge from a first-in, first-out type of mass-flow bin. A mass-flow bin is a conventional bin with a hopper of slope and discharge aperture that permits all particles, including those along the wall, to move during discharge. First-in, first-out mass-flow bins are characterized by the movement of all particles at virtually the same vertical velocity and discharge in the same order as charged.

Vertical segregation of free-flowing solids, unlike poor-flowing solids, can be rectified by the use of commercially available blending bins. Jenike and Johanson<sup>2</sup> report, however, that under certain conditions poor-flowing solids can be blended by recycling them in conventional bins. The particles must be very small or fall within a narrow size range and have a density and shape not subject to horizontal segregation. In addition, the bin must be of the mass-flow type, not the first-in first-out variety, and every horizontal cross section must have a substantial velocity gradient. Recycle blending has been effected with different bin-hopper configurations and bin-loading methods, including a short bin (height not exceeding one-half the diameter) and a steep hopper with central loading.<sup>3</sup> Also used effectively has been a taller bin (height greater than one-half the diameter) with symmetric side loading and a flatter hopper.<sup>4</sup>

This report describes a system that was developed to recycle and horizontally and vertically blend coals for subsequent use in calibrating nuclear-based instruments to continuously measure coal moisture and sulfur content.<sup>5</sup> The system is capable of recycling 3,000 pounds of coal of any size range within 3 by 0 inch and moisture content to 10 percent at up to 50 tph.

#### SOLIDS BLENDING SYSTEM

Figures 1 and 2 show the recycling system. Buckets discharge the coal through an automatic sampler and into a distributor<sup>6</sup> at the top of the blending bin. The distributor, shown in figure 3, is a rotating, oscillating chute that spreads the particles uniformly over the horizontal cross section of the bin, thereby producing a smooth bed that minimizes cone tumbling and

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<sup>2</sup>Jenike, Andrew W. Storage and Flow of Solids. Utah Engineering Experiment Station, Bull. 123, v. 53, No. 26, November 1964, 198 pp.

Johanson, J. R. In-Bin Blending. Chem. Eng. Prog., v. 66, No. 6, June 1970, pp. 50-55.

<sup>3</sup>Work cited in footnote 1.

<sup>4</sup>Work cited in footnote 1.

<sup>5</sup>Stewart, R. F., A. W. Hall, and J. L. Konchesky. Plant Tests of a Neutron Moisture Meter for Coal. Min. Cong. J., v. 56, No. 11, November 1970, pp. 44-48.

Stewart, Robert F., and William L. Farrior, Jr. Feasibility of Continuous Ash Measurement of Coal. Preprints, Div. of Fuel Chem., ACS, v. 8, No. 3, Aug. 31-Sept. 3, 1964, pp. 192-197.

<sup>6</sup>Konchesky, J. L., and E. C. Oldaker. Rotary Particle Distributor for Minimizing Particle Size Segregation in a Bin. U.S. Pat. 3,576,262, Apr. 27, 1971.



FIGURE 1. - Coal Recycling System.

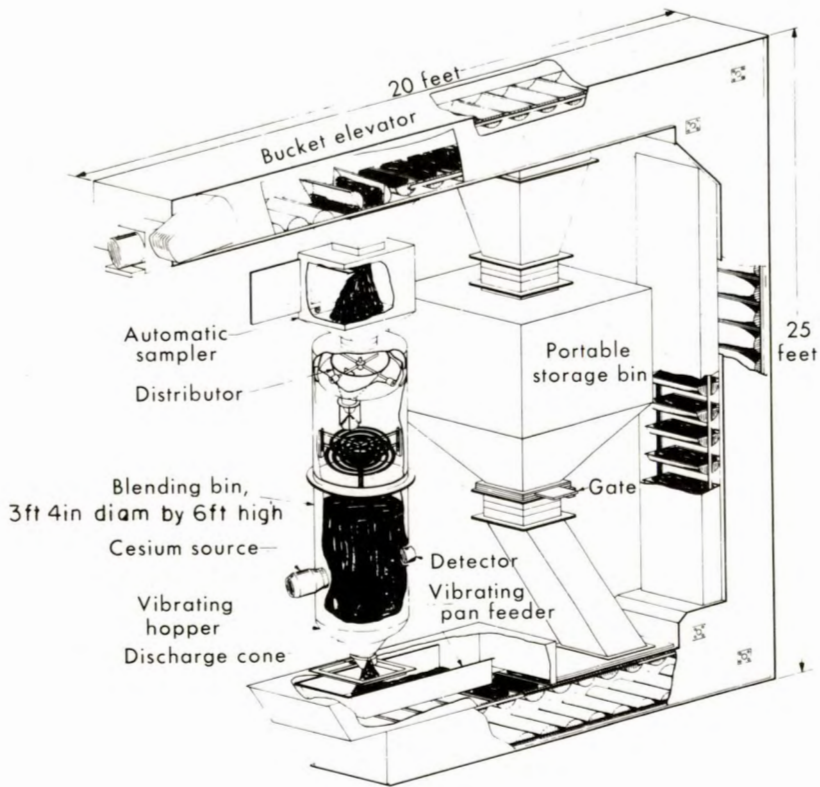
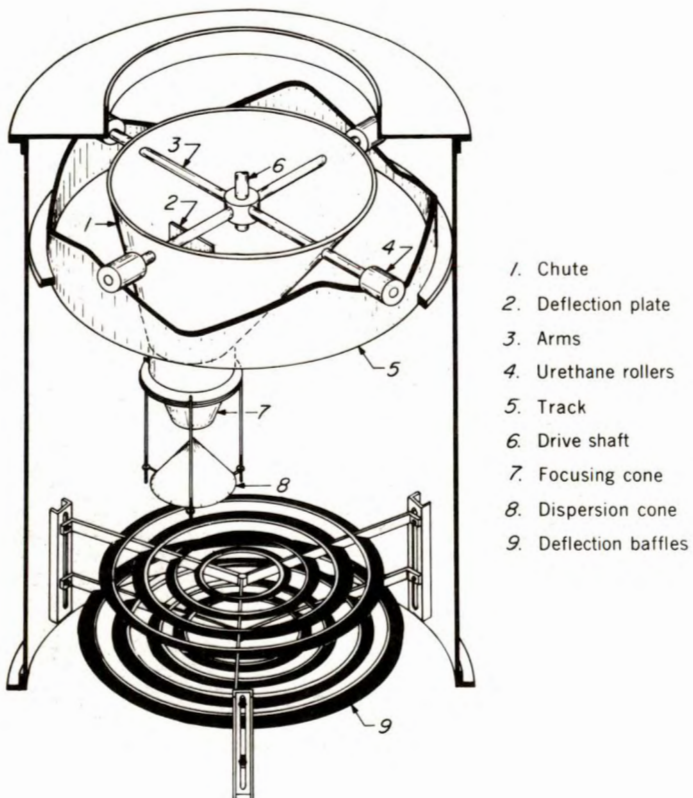


FIGURE 2. - Diagram of Coal Recycle System.



- 1. Chute
- 2. Deflection plate
- 3. Arms
- 4. Urethane rollers
- 5. Track
- 6. Drive shaft
- 7. Focusing cone
- 8. Dispersion cone
- 9. Deflection baffles

FIGURE 3. - Particle Distributor.

horizontal segregation. Coal from the blending bin is discharged through a vibrating hopper onto a vibrating pan that feeds the bucket.

The cross-sectional area of the distributor discharge (focusing cone) is about 25 percent greater than that of the discharge cone on the vibrating hopper at the bottom. This setup minimizes the possibility of plugging and still permits effective focusing of the coal stream onto the dispersion cone. A variable speed motor, coupled by a double universal joint to the drive shaft of the chutes, rotates and oscillates the distributor. The chute is oscillated by means of arms that ride along a track having several smooth scallops resembling a sine wave.

Smoothness of the bed surface is controlled by changing the width and location of the deflection plate, by adjusting the angle and location of the dispersion cone, and by choice of number, position, and angle of the deflection baffles. The latter are shaped like frustrums of cones.

A gamma-ray meter, consisting of a cesium-137 source, and an ionization chamber detector (fig. 2) continuously indicate changes in bulk density of the coal about 50 inches below the surface of the bed.

#### TEST PROCEDURE

The mixing performance of the unit was evaluated in a series of runs in which 1/2- by 0-inch Pittsburgh-seam bituminous coal containing about 6 percent moisture was circulated through the system. The size range of 1/2 by 0 inch provided a good test of the blending capability of the system, since particles differing this much in size have a considerable tendency to segregate. The vibrating hopper had a 4-inch discharge cone that permitted recycling of a 3,000-pound batch of the coal at 9 tons per hour. The diameter of the focusing cone was 5 inches; the distributor was rotated at 8 rpm. Deflection baffles were not used.

Successful performance required the effective blending of different size particles, both horizontally and vertically, as they flowed through the blending bin. While the coal was being transferred from the storage bin to the blending bin, samples were cut from the stream with the automatic sampler to determine vertical segregation in the blending bin before the recycling operation. Samples were also cut at 2-minute intervals during recycle to follow the progress of vertical desegregation or blending and to measure the quality of the blend. The gamma-ray meter was also operated during recycle to determine whether bulk density measurement could be used to monitor the vertical mixing operation. After recycling to vertically mix the coal was terminated, coal in the mixing bin was manually sampled over horizontal (to the bed surface) cross sections at 3, 5, and 6 feet above the bottom of the bin to determine the horizontal segregation. These samples were analyzed for particle size by sieving on shakers for 5 minutes through 4-, 8-, and 20-mesh sieves. Since the plus-4 mesh size was found to segregate more than the other sizes, subsequent evaluation of the mixing was based on the extent of desegregation of this size.

The test procedure was repeated, without operating the distributor, to evaluate the horizontal desegregation effectiveness of the distributor and to determine whether vertical blending could be achieved without horizontal blending. Such blending would appear to be of commercial interest, since it would be advantageous to economically effect vertical desegregation without the expense of horizontal desegregation.

Two series of tests were conducted, each series consisting of one recycling period with the distributor and another of equal duration without it.

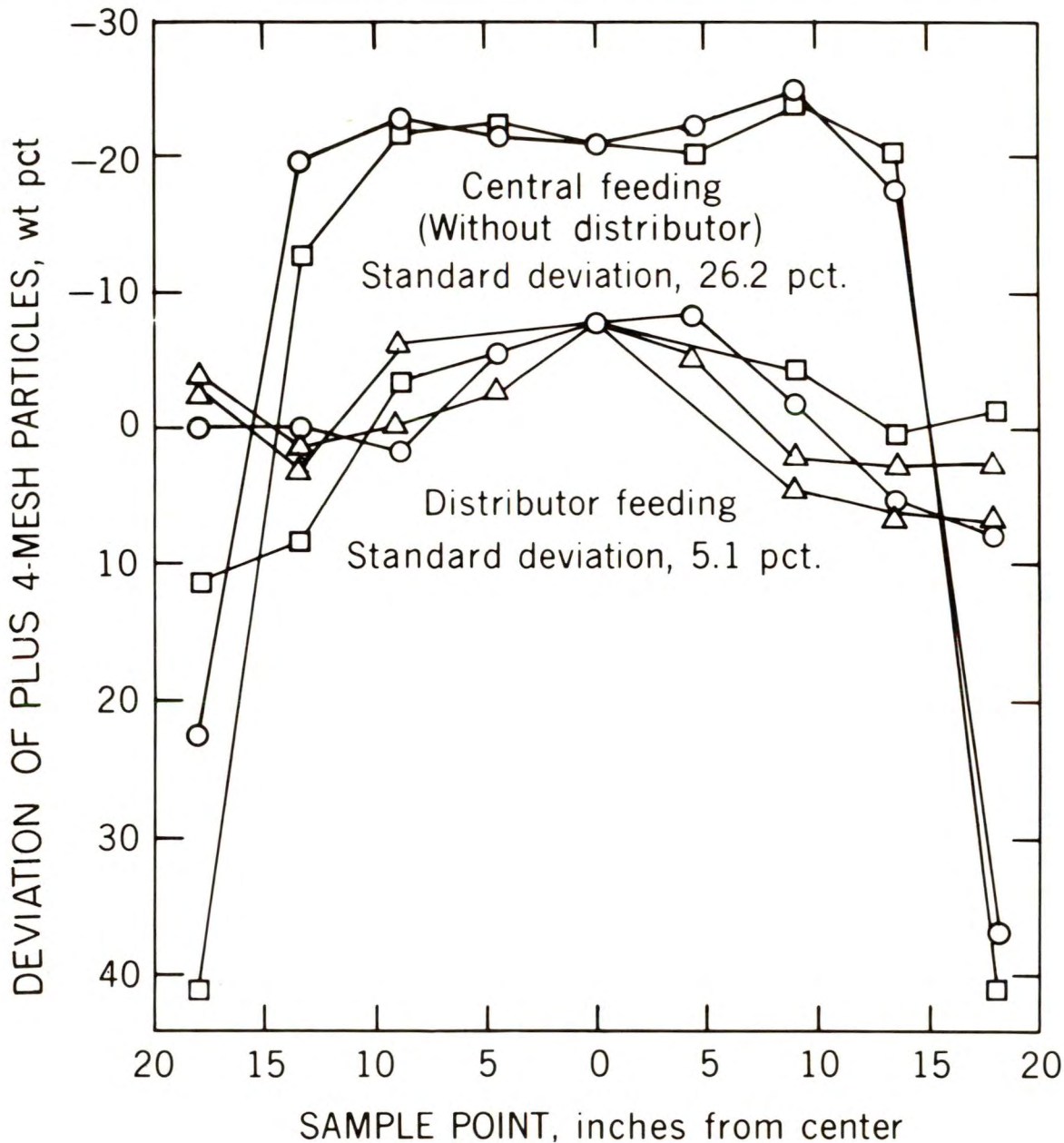


FIGURE 4. - Desegregation at 5-Foot Level, First Test Series.

Recycling time in the first series was 1 hour and in the second series 1-1/2 hours.

The effectiveness of blending moisture with the coal was also used as a determinant of the size mixing effectiveness of the system. The horizontally distributed coal was sampled to determine vertical moisture variations after it had been recycled to the extent deemed necessary to achieve size mixing. Recycling was carried out for several hours. Samples for moisture analysis were cut at 10-minute intervals as the coal slowly air dried.

## EFFECTIVENESS OF THE BLENDING

### Horizontal Blending of Particles

Horizontal blending or desegregation achieved at the 5-foot bed level with and without the distributor, is shown in figure 4 for the first test series. Deviations between the weight-percent of the plus-4-mesh particles in the samples and the weight-percent in the vertically blended recycling coal are plotted as a function of sample location across various bin diameters. For central feeding, the samples were taken along two perpendicular bin diameters; for distributor feeding, the samples were taken along four diameters at 45-degree intervals.

Distances of the data points above and below the zero line on the y-axis shows the variation in amount of plus-4-mesh particles from the corresponding amount in the recycling coal. Points above the zero line (negative deviation) indicate fewer plus-4-mesh particles; points below indicate more. Assuming that the standard deviation represents horizontal segregation, it is apparent that considerable horizontal desegregation was achieved with the distributor. For the other bed levels in the first test series and all bed levels in the second series, the standard deviations with distributor operation ranged from 5.7 to 6.6 percent.

### Vertical Blending of Particles

Figures 5 and 6, respectively, compare vertical particle blending for central and distributor feeding from the first and second test series. Considerable vertical segregation of the coal particles is evident in the blending bin before each recycle test in each series; coal at the top of the bin is comprised of about 70 percent plus-4-mesh particles, while coal in the lower two-thirds contains between 10 and 30 percent. As recycling progresses, a cyclic particle-size peak, reflecting vertical segregation, is evident with each passage of coal through the bin.

Eventually, these fluctuations diminish, indicating progressive blending of the particles. Bulk density values, for central feeding (fig. 5) and distributor feeding (fig. 6), show the same trend without the time and expense of sampling and analysis.

It is apparent that recycling achieved effective vertical blending, and that central feeding was equally as effective as distributor feeding. With

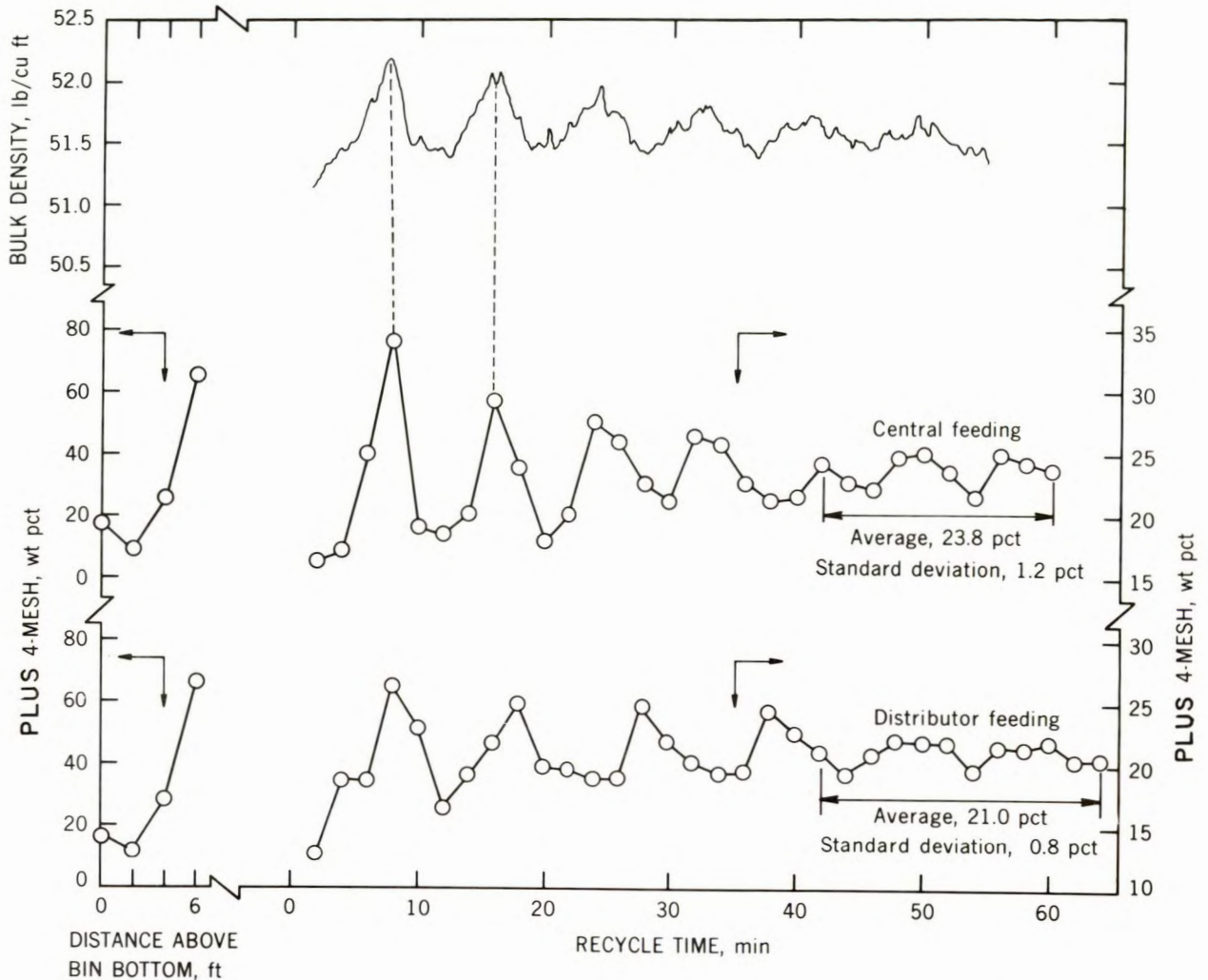


FIGURE 5. - Segregation by Bin Filling Compared With Vertical Blending by Recycle, First Test Series, 1-Hour Periods.

either feeding method, about four passes of the coal, or about 40 minutes, was required to effect vertical blending. Also, the quality of the blend was virtually the same; the standard deviation of the plus-4-mesh particles from the average after 40 minutes of recycle was about 1 percent for either feeding method. Since the results in each test series were very similar, vertical blending by recycle with either central or distributor feeding appears to be reliable.

#### Vertical Blending of Moisture

Figure 7 shows the typical vertical distribution of moisture in the horizontally distributed, recycling coal over a 5-1/2-hour period after the coal had been vertically blended with respect to particle size. The solid line, drawn by the method of least squares to fit the data points, is a drying-rate curve representing the gradual drying of the coal during recycle. The

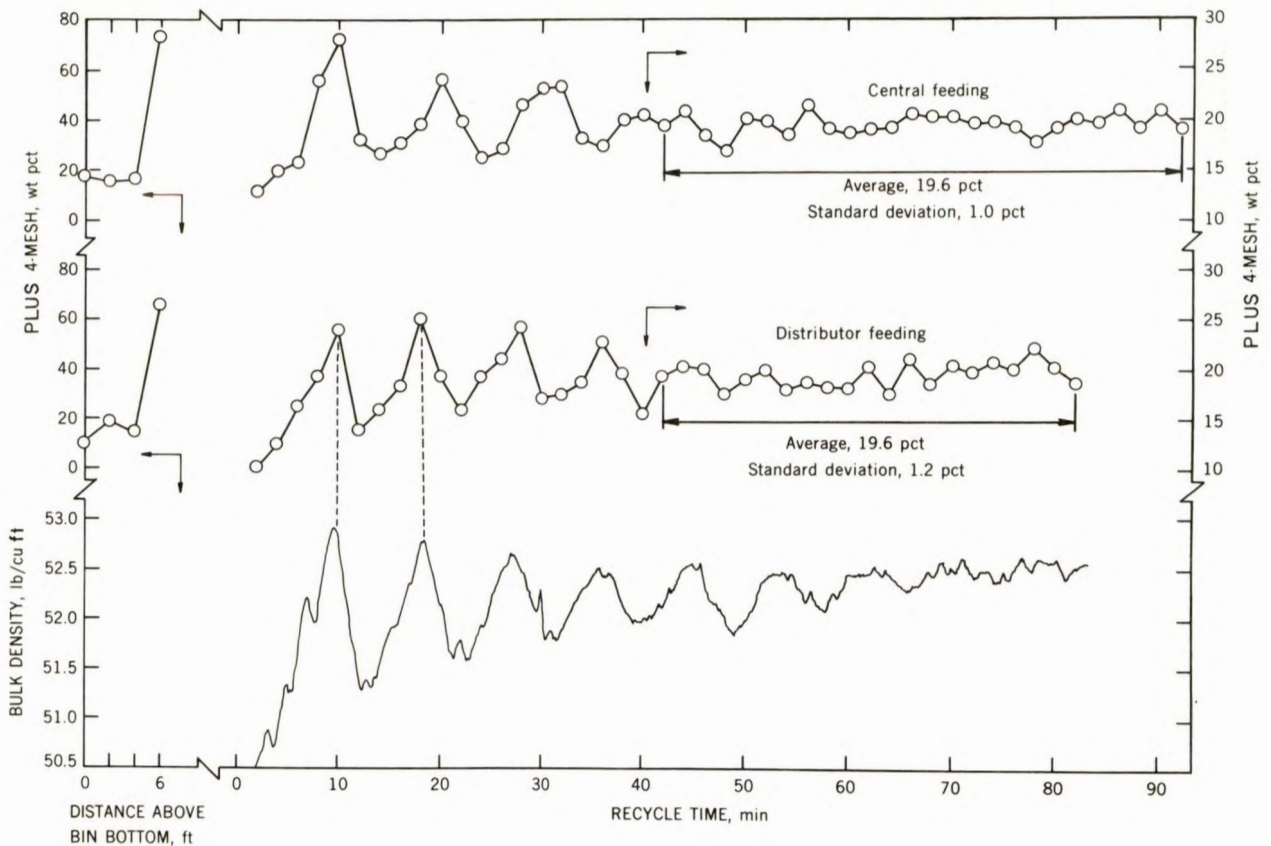


FIGURE 6. - Segregation by Bin Filling Compared With Vertical Blending by Recycle, Second Test Series, 1½-Hour Periods.

standard deviation of the points from the solid line is only  $\pm 0.18$  percent, which is even less than the 0.3 percent moisture deviation allowed by ASTM procedure for the moisture analysis of duplicate coal samples in the same laboratory. This accuracy indicates excellent blending of the moisture. The same degree of vertical moisture blending probably could also be achieved by recycle with central feeding.

#### SUMMARY AND CONCLUSIONS

A through-bin recycling system was developed for the horizontal and vertical blending of coals having a wide range of size and moisture content. Since wet coals exhibit poor flow characteristics, other solids would probably be effectively blended. Horizontal desegregation was achieved by means of a distributor that spread the particles evenly across the bed during recycling. The distributor and central feeding techniques required virtually the same amount of time to achieve comparable vertical blending. Solids circulated during the tests were also blended with respect to composition, as was revealed by moisture analyses after the size mixing procedure. Continuous bulk-density measurement of the solids flowing through the bin was also an effective monitor of vertical blending.

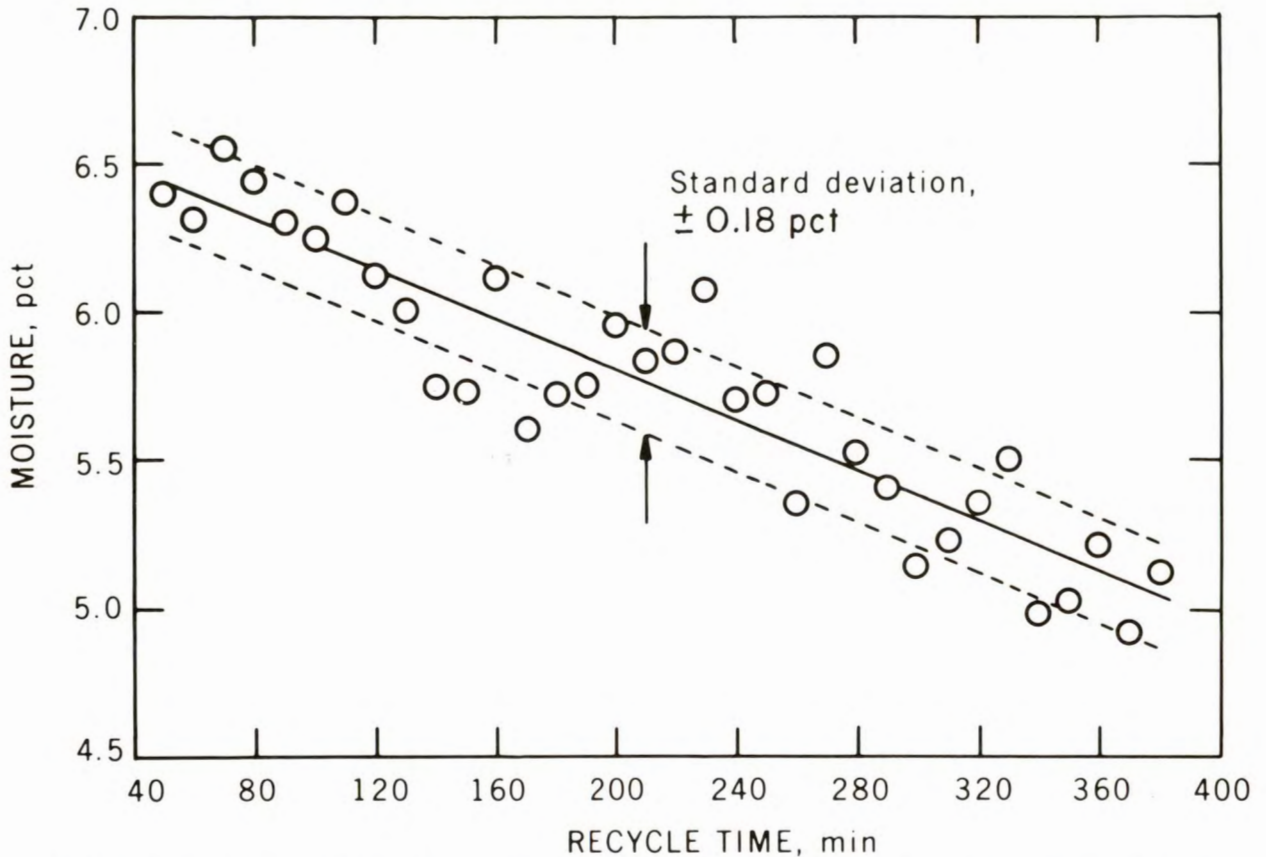


FIGURE 7. - Vertical Distribution of Moisture in Recycling Coal Vertically Blended With Respect to Particle Size.

Coal particles ranging in size from 1/2 to 0 inch, in about 3,000-pound lots were vertically blended in 40 minutes with a recycle rate of 9 tons per hour. The entire batch had to be cycled four times to achieve blending, but increased recycle rates would likely provide acceptable blending in proportionately less time.

For this system, the time required for vertically blending solids having approximately the same physical characteristics as the coal utilized in these tests, including the same initial vertical segregation, can be approximated by the equation  $T = \frac{4W}{F}$ , in which

T equals the recycling time in minutes,

W is the weight of the solid batch in pounds,  
and

F is the recycling rate in pounds per minute.

Equations for materials having different characteristics will have to be developed empirically.