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AGGREGATE OPTIMIZATION USING A Y-BLENDER

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Equipment and procedures were developed to use large samples of coke (2-20 kg) to determine optimum aggregate sizing. The equipment was made from 100-200 mm diameter pipe welded into the shape of a "Y". The apparatus can be partially filled with coke and rotated manually to produce good blending. Bulk density is calculated from the weight and volume of the coke after blending. Rather than discard an entire sample after testing, about 5% of the charge is removed and the same amount of a pure fraction (coarse, intermediate, etc.) is added. After a series of tests, resultant data are smoothed and plotted on a triangular diagram. For tests of typical cokes, a single maximum bulk density peak was found on the bulk density vs composition response surfaces. This peak was fairly flat near the top--more like a plateau than a sharp spike. Four samples of coke taken over a two-month period showed only a slight change of the maximum density composition with time.

Introduction

Coke for making anodes is ground into fractions designated butts, coarse, intermediates, and fines. The butts may have a maximum particle size up to 30 mm, while the fines are mostly smaller than 0.1 mm, (200 mesh) (Figure 1). To achieve the highest anode density, these four fractions must be proportioned to provide a good "fit" of these various particle sizes.

Bench-scale tests have been used for many years to find the maximum dry bulk density formulation (MDBD). Typically, in such a test, 400 g of blended coke is placed in a 1000 ml graduated cylinder and vibrated to minimum volume. A series of tests with a range of compositions can be plotted on triangular graph paper to show iso-density contours.

This method can give reasonably good results for relatively fine sizings; however, there are some drawbacks. Obtaining a 400 g sample which is representative of commercial production can cause some error. Also, the procedure has a certain experimental error inherent. A more serious problem can be the placing of large butts particles in a 60 mm diameter graduate.

To overcome some of these problems, a larger apparatus has been developed and techniques have been modified which appear to produce better results.

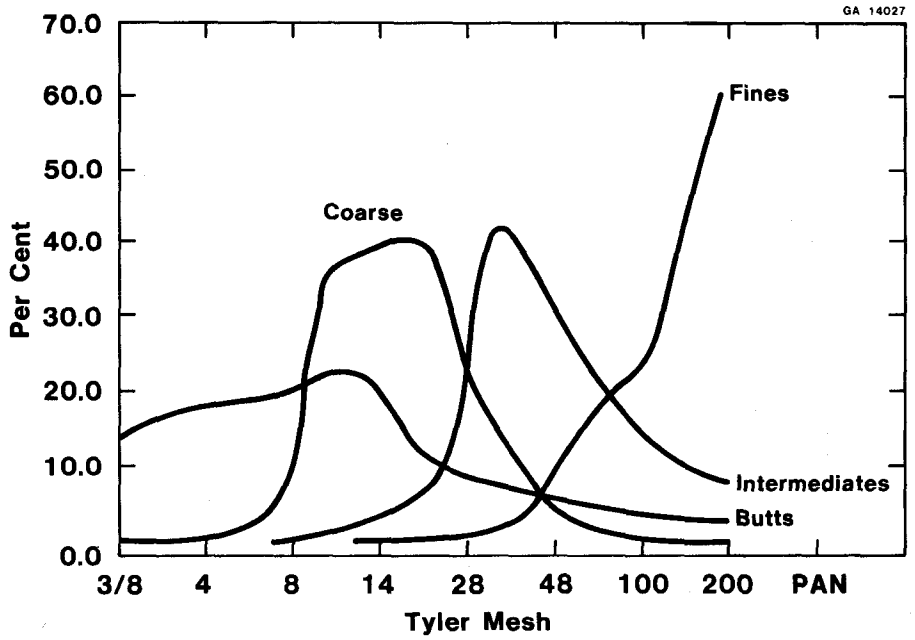

FIGURE 1. SIEVE ANALYSIS OF TYPICAL COKE SAMPLES

Procedure

A piece of pipe was cut and then welded into the shape of a capital letter "Y" (Figure 2). For obvious reason, this was referred to as a Y-blender. By capping the open ends of the pipe after partially filling the blender, and rotating the device, a thorough blending of a relatively large coke sample was achieved. Blenders were made from pipe diameters of 100 mm, 150 mm, and 200 mm. Sample sizes ranged from 2400 g to 18000 g. The volume of the coke sample was measured by placing a closed-end tube on top of the coke when the "Y" was at rest in its inverted position. A ruler attached to the closed tube provided adequate accuracy. A vibrator was attached to the blender to produce higher density before the volume was measured. Density was calculated from the weight and volume measurements.

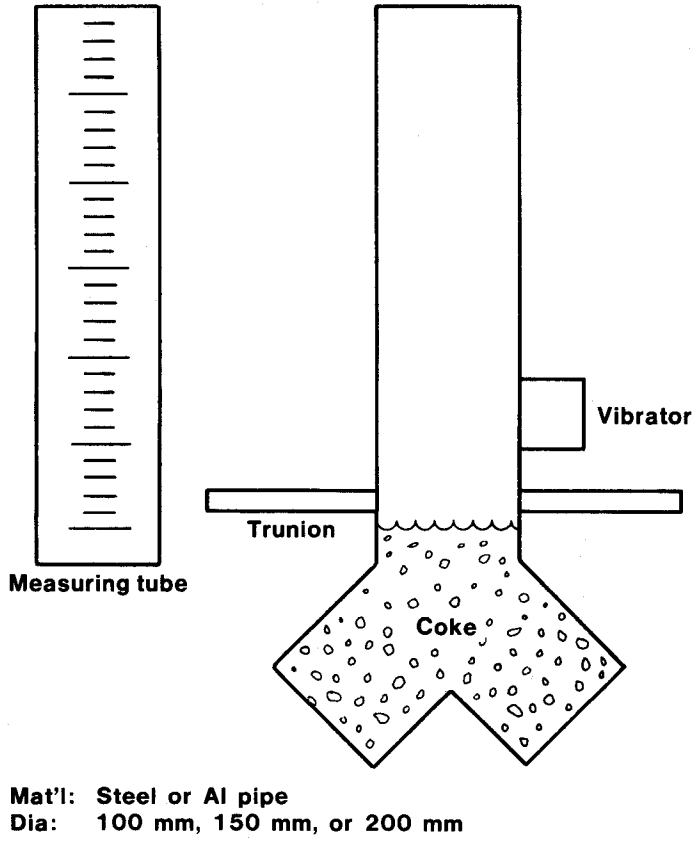

FIGURE 2. Y-BLENDER

For a typical coke sample, the 150 mm diameter Y-blender was used with an 8800 g aggregate charge. Butts content was kept constant at 20% throughout the tests. To start the test, the following charge was used:

8800 g aggregate x 20% butts = 1760 g butts
8800 g aggregate - 1760 g butts = 7040 g coke

The coke part of the aggregate was chosen to be 30% intermediate, and 70% fine.

7040 g coke x 30% = 2112 g intermediate
7040 g coke x 70% = 4928 g fine

This composition is shown at the bottom of the vertical line on the triangular diagram Figure 3. The corners of this triangle represent coarse, intermediate, and fine coke, as it was drawn from the storage silos. This is not the same as the 28 mesh and 100 mesh labels often used on this type of diagram. The butts content of 20% is not represented on this diagram, but was constant throughout the test.

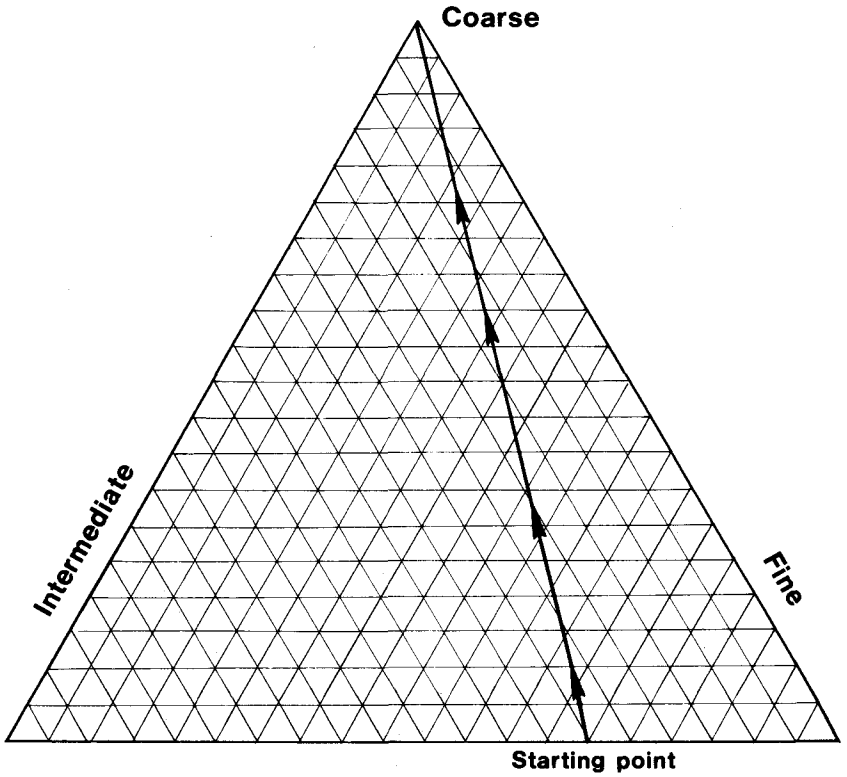

FIGURE 3. LOCUS OF COMPOSITION BY REPEATED COARSE ADDITIONS

To start the test, the density was determined for the starting composition:

1760 g butts
2112 g intermediates
4928 g fines
8800 g aggregate total

The density was determined before and after vibration. A 500 g representative portion of the 8800 g was then removed and replaced with 100 g butts and 400 g coarse coke. This left the butts content unchanged and left the ratio of intermediates to fines unchanged; but increased the proportion of coarse coke in the charge. In other words, the composition moved upward on the vertical line toward the top (coarse) corner of the triangle. This procedure of determining the density, withdrawing a 500 g portion and replacing it with butts and coarse coke was repeated many times. Results are shown in Figure 4. This is, in effect, a vertical slice (perpendicular to the triangular diagram).

After this part of the test was completed, the Y-blender was emptied and charged with a new composition: 49% coarse, 51% fines, not including the standard 20% butts. A new series of tests was run by adding increments of intermediates (Figure 5). A third series was run starting at 36%C, 64%F, and working toward 40%C, 60%I.

Results and Discussion

The data from each of the three tests (coarse additions, intermediate additions, and composite additions) were plotted separately as in Figure 4 and Figure 5. Data from these plots were then transferred to a triangular diagram and iso-density contours were drawn (Figure 6). A certain amount of smoothing was done in the construction of the individual curves, e.g. Figure 4 and Figure 5. A small amount of smoothing was then necessary to fit these three sets of data onto the triangular diagram. The peaks of each of the three curves coincided very well on the triangular diagram; however, the intermediates-addition test showed a maximum density 0.01 g-cm^{-3} higher than the other two tests. It appeared this was a consistent bias throughout this test so the contours were smoothed accordingly.

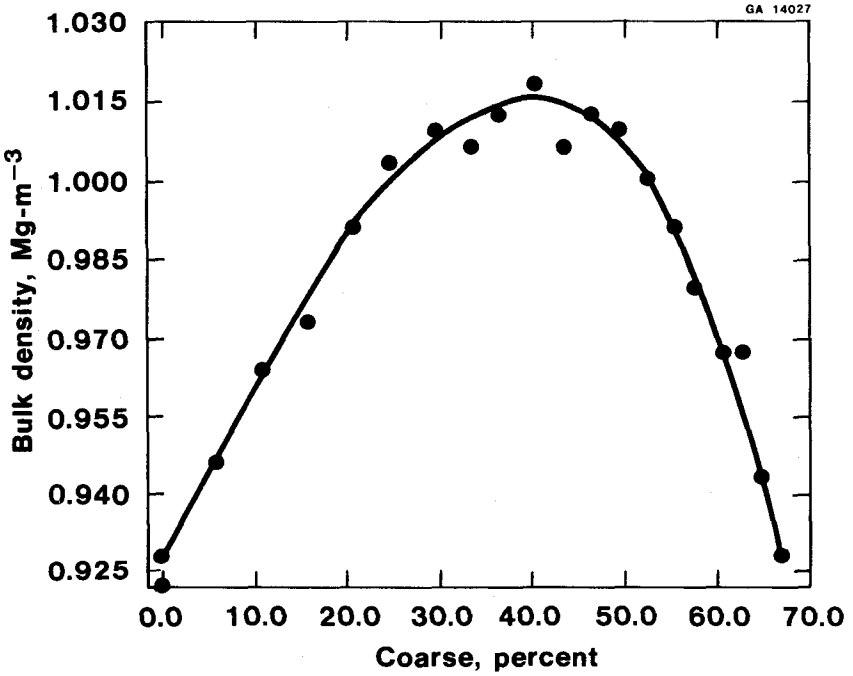

FIGURE 4. Y-BLENDER BULK DENSITY FOR REPEATED ADDITIONS OF COARSE COKE

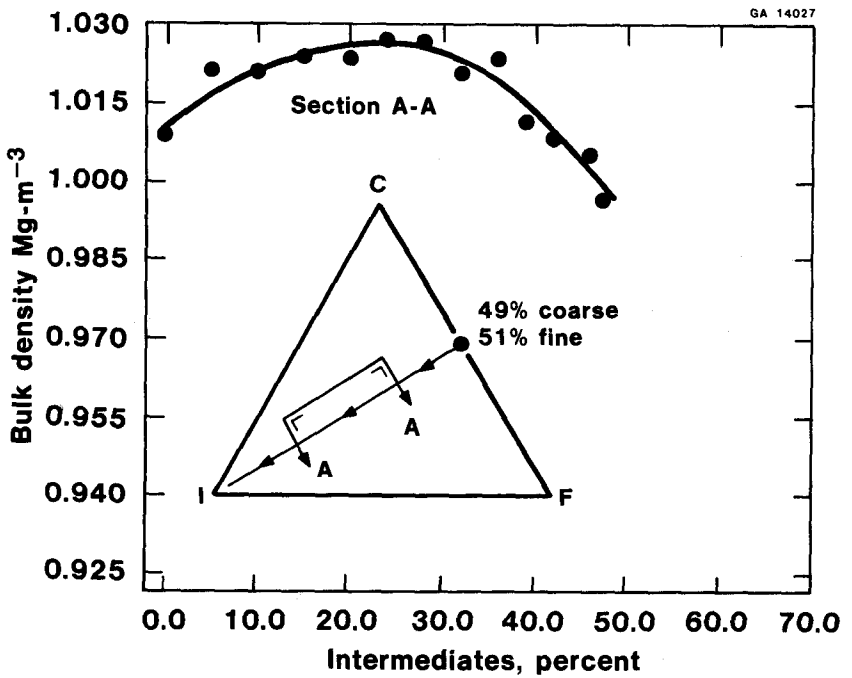

FIGURE 5. Y-BLENDER BULK DENSITY FOR REPEATED ADDITIONS OF INTERMEDIATE COKE

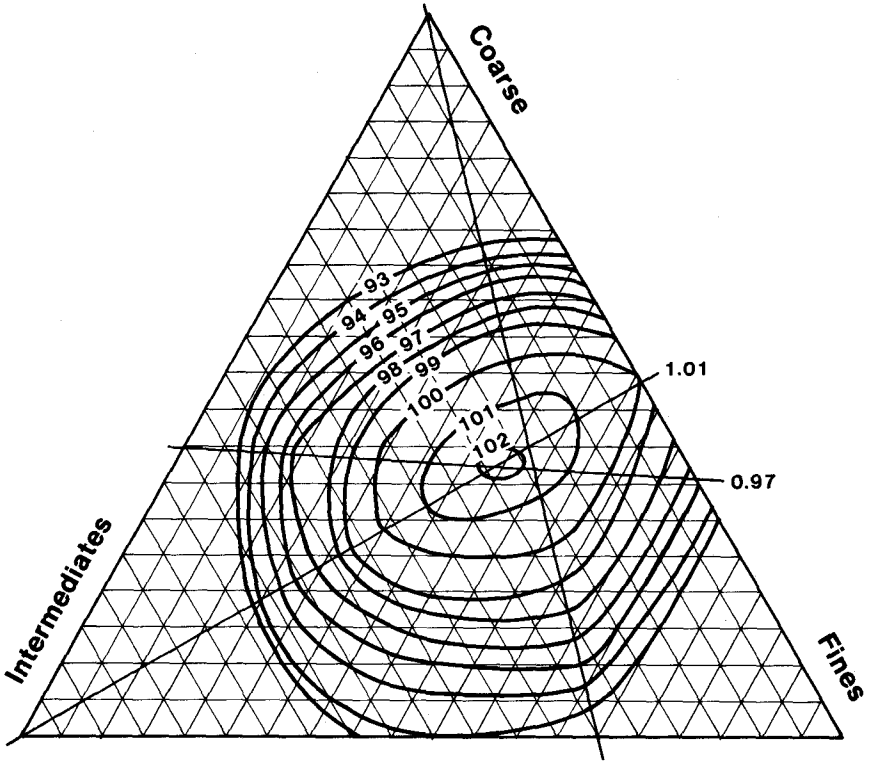

FIGURE 6. Y-BLENDER ISO-BULK DENSITIES FOR A TYPICAL COKE. BUTTS CONTENT OF 20% IS NOT SHOWN HERE. NO VIBRATION.

The reason for this small discrepancy could be due to the initial intermediates-addition coke sample not being representative of the overall sample. Possibly a greater proportion of large butts particles was included in the initial charge.

Sieve analyses of common points for the three series showed that the intermediate-addition test differed in composition, apparently due to problems of segregation. However, this inconsistency of 0.01 g-cm^{-3} is not so serious as the experimental error commonly encountered in the glassware procedure.

The overall response surface (Figure 6) shows a single maximum, roughly near the center of the triangular diagram. The slope of this surface is fairly steep, near the edges of the triangular diagram, but not so steep as the maximum is approached. The high point could almost be considered a plateau rather than a peak.

This indicates that the maximum density composition is somewhat forgiving. While small gains in density can be expected if very good control can be achieved, conversely, reasonably small penalties will be incurred for small excursions from the MDBD peak.

The discussion above was for density data taken without vibration. By vibrating the apparatus, the coke density was increased appreciably, but the general results were not.

Figure 7 shows the MDBD peak and the iso-density contours for vibration to be virtually identical to Figure 6 (unvibrated). In addition to requiring more time, vibration introduces the possibility of segregating the coke since the fines have a tendency to trickle down through the coarser particles during vibration.

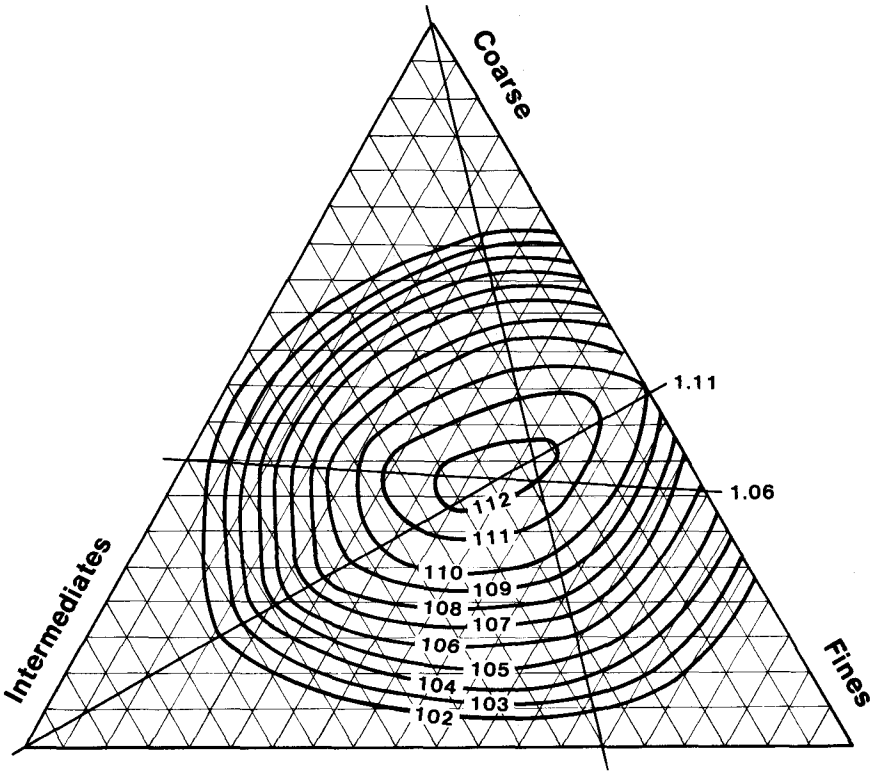

FIGURE 7. ISO-BULK DENSITIES FOR SAME COKE AS IN FIGURE 6. BUTTS CONTENT OF 20% IS NOT SHOWN HERE. BLENDER WAS VIBRATED.

Similar tests were run using four samples of coke from another plant collected over a two-month period. The coke was taken from the automatic sieve analyzer, and was thus separated into three fractions: +28 mesh, 28 x 100 mesh, and -100 mesh. The separation is not quite so good as a Ro-Tap separation, but it is consistent and is used as the basis for control.

Samples of this type simplify the computation and presentation of data since the butts are irretrievably enmeshed in the sample and need not, nor cannot, be handled separately. Butt return is typically 20%, which appears mostly in the +28 mesh fraction.

For this series of samples, a 4000 g coke charge was used in the 100 mm diameter Y-blender. Coordinates on the triangular diagram are in terms of Tyler mesh size rather than the C-I-F designation used for the first example. The same strategy was used, first making tests with +28 mesh additions, and then making 28 x 100 mesh additions. A third composite addition was then made to complete the data.

Typical results for one of the four samples are shown in Figure 8. Again, only a single peak was seen in each case, and the peaks were more

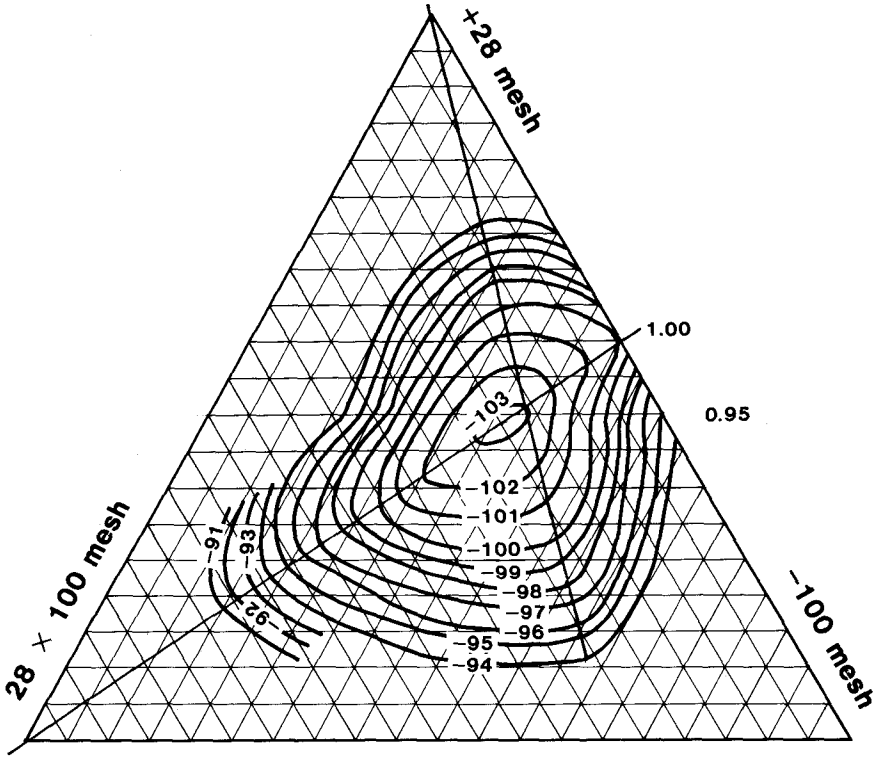

FIGURE 8. ISO-DENSITY CONTOURS FOR A BLEND OF TWO COKES AND 20% BUTTS

like plateaus than sharp spikes. The MDBD compositions are summarized in Figure 9 along with the historical target. This indicates that the target has been close to the MDBD composition; however, slightly more fines might be used. There was no indication that the MDBD composition changed markedly with time. This, despite the fact that two different cokes were blended.

It should be noted that all of this work was aimed at establishing the MDBD formulation; that is, the Maximum Dry Bulk Density. It could be argued that the addition of pitch and compaction to substantially higher aggregate bulk density might change the maximum density composition. This has not been unequivocably settled.

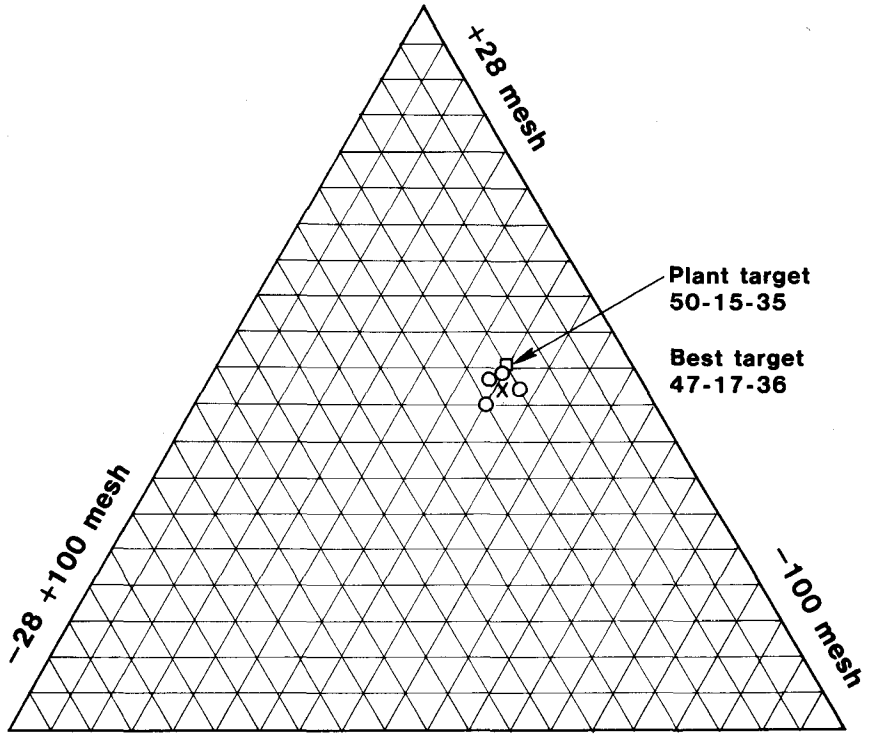

FIGURE 9. SUMMARY OF DATA FOR FOUR TESTS OVER A TWO-MONTH PERIOD

A series of 50 mm diameter laboratory anodes were pressed from the second set of coke samples. Seven compositions were chosen to coincide with coarse additions from one of the test series. Pitch content was 17% in all cases. The Green Apparent Density vs + 28 mesh coke plot (Figure 10) agreed reasonably well with the dry bulk density data. Baked data were harder to interpret since the pitch was far from optimum in most of the samples. About all that can be said is that no strong evidence of a displacement of the MDBD peak was found. Extensive work would be needed to make enough laboratory samples to prove this.

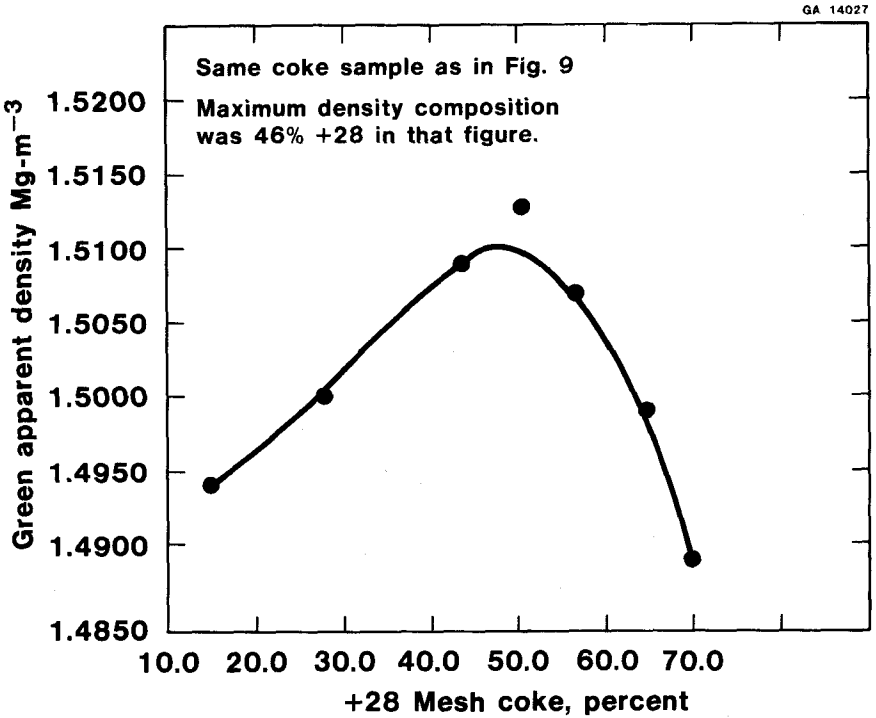

FIGURE 10. GREEN APPARENT DENSITY OF PRESSED LABORATORY SAMPLES

Conclusions

1. For blends of butts, coarse, intermediate, and fines, a single, unique composition exists which will produce the maximum dry bulk density.

2. This maximum takes the form of a rounded hill or plateau rather than a steep peak.

3. There is some evidence to indicate that the MDBD composition does not shift rapidly with time. (Introduction of a coke of greatly different density might cause it to do so, however.)

4. The Y-blender, has been shown to be a preferred device for determining MDBD composition.

Reference

U.S. Patent 4,283,148, "Apparatus and Method for Solid Particle Bulk Density Measurements." Richard W. Peterson, Lower Burrell, PA, assigned to Aluminum Company of America.