DOE/PC/91290--T9

# TECHNICAL PROGRESS REPORT #10

**Title:** Non-Intrusive Measurement of Particle Charge: Electrostatic Dry Coal Cleaning (DE-FG22-91PC91290)

**Organization:** Center for Applied Energy Research
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**Report Period:** 10/1/93 - 12/31/93

**Grant Period:** 8/29/91 - 8/28/94

## 1. Grant Objective: No change

## 2. Technical Approach Changes:

During this period, data quantifying the effect of gas velocity on particle charge was collected for two coals and glassy carbon. Also, various charging techniques were evaluated and charge saturation was investigated. The particle feeder enclosure was redesigned and constructed of stainless steel to handle small positive pressures and allow easier particle access.

## 3. Progress Report by Task:

### Task 1. Sample Acquisition and Preparation

The two coal samples evaluated during this period were from the Leatherwood seam in Harlan County, KY (a high rank bituminous) and the Herrin seam - Illinois #9 from Saline County, IL (a vitrinite rich bituminous). The size distributions of the two high volatile coals, after they were prepared for charging tests, were evaluated using a "Granulometre 715" laser based size analyzer. Representative results of these evaluations, shown in Figures 1 and 2, show the desired narrow size distribution.

## Task 2: PDPA - Charge Measurement

### Summary of Work

The effect of charging velocity on different coals and glassy carbon was evaluated. As in previous tests on other materials, it was found that the charge per unit mass increased linearly with increasing gas velocity, within the range of velocity tested.

A copper tribocharging cyclone was designed and built with the objective of reducing the exiting charged particle velocity. With a lower particle velocity, particle travel time would increase and charge dissipation measurements would be feasible. It was found that rather than add particle charge, the cyclone caused particles to lose charge, presumably due to a lower frictional velocity within cyclone.

An evaluation of different charging system geometries was conducted. A copper in-line mixer and copper tubing loops produced similar particle charge results. It was discovered that initial results using new copper tubing produced lower particle charges that did older "seasoned" copper. After continuous operation for approximately 30 minutes, results from the new loop would coincide with those from older systems. It is presumed that a layer of oxidation was removed from the surface of the new copper by the abrasive particles.

It was found that as the amount of time in contact with the tribocharging loop increased, the average particle charge approached a maximum, indicating a degree of charge saturation was occurring.

As described in the last report, an electrolytic solution was used to collect and measure particle charge. As a further improvement of that technique, the electrolyte was placed in an ultra-sonic mixing bath to ensure complete and immediate immersion of charged particles into the solution. The ultra-sonic bath, combined with the addition of a surfactant proved helpful for evaluation of small and hydrophobic particles.

The particle feed system was rebuilt to simplify the experimental procedure. A stainless steel tank with better sealing and easy access to the vibratory feeder was constructed to replace the original plastic chamber.

### Experimental Results

1. Comparison of various chargers.

An investigation to determine the effect of charger geometry on particle charge was conducted. Two different charger geometries were evaluated; a coil or looping system and an in-line static mixer similar to those used by PETC in their tribocharging experiments. The mixer, installed inside the 1/4" copper particle pneumatic transport tube, was 10" long, constructed of copper and consisted of 32 twisted sections. The copper coil charger was constructed of 1/4" tubing coiled to a 4.5" diameter. The number of loops varied between one and six.

Silica particles (60μ diameter) were fed at a constant volume fraction of 70 ppm in an average transport gas velocity of 16.2 m/s. The results are shown in Figure 3. The first bar represents charge (presented as current flow from the electrolytic solution) generated by particles traveling through the in-line mixer. The second - sixth bars show the charge induced by a copper coil with one - six loops, respectively. These results show that for a copper coil of more than two loops, the average induced particle charge is constant (charge saturation occurs). The charge induced by the in-line static mixer was similar to that of the multiple loop coils. Particle charge results described in previous reports were all produced with a copper coil of 2 or 3 loops.

The fact that the induced current approached a constant value with increasing charger length indicates that the particles were being charged to their Gaussian limit. Since the Gaussian limit is dependent on particle size, which in this situation was narrowly distributed, one would expect a narrowly distributed charge for all the particles. However PDPA results reported previously showed that the particle charge could be widely distributed and that the span of the charge distribution is a function of gas velocity and particle mass flowrate. This can be explained by considering the "competition" between particles for contact with the charging surface. As the velocity or particle density increases, the probability of particle - wall contact becomes less.

A copper cyclone was designed, fabricated and installed downstream of the charging unit. The objective was to decrease the particle velocity to enable charge dissipation measurements. Attempts to measure the dissipation rate without a cyclone failed because the particle velocity was too high (10 m/s) to allow significant charge decrease before entering the electrolytic solution. By using the cyclone, particle velocity was decreased by up to 90%, however, the particle charge was decreased by a similar amount. Electric current measurements showed that the particles released their charge to the cyclone rather than maintain or accumulate additional charge. This occurred regardless of weather the cyclone was grounded or isolated.

2. Charge measurement data

Average particle charge as a function of gas velocity is shown for the Leatherwood seam coal in Figure 4 and the Herrin seam coal in Figures 5 and 6. While an effort was made to maintain a constant particle feedrate for each test, some variability still occurred, primarily with the finer particle sizes. The Leatherwood feedrate was 3.06 mg/s while the Herrin feedrate of similar sized particles was 3.09 mg/s (Figure 5). For the finer sized Herrin particles, shown in Figure 6, the feedrate was 4.81 mg/s.

Consistent with previous reported results, the average particle charge increased linearly with increasing gas velocity (within the range of gas velocity tested). The charge magnitude for the two coals at the same particle size was nearly the same. The line representing the charge magnitude for the finer sized Herrin coal shows a slightly higher slope than that for the coarser particle size.

Figure 7 shows particle charge as a function of gas velocity for fine sized glassy carbon particles. The average particle charge was 3 to 4 times less than that for similarly sized coal particles. This may be explained by the fact that the feed rate for this test was 16.8 mg/s, almost 4 times that of the coal particles. The difficulty in controlling the feedrate at finer particle sizes was related to problems with the vibratory feeder.

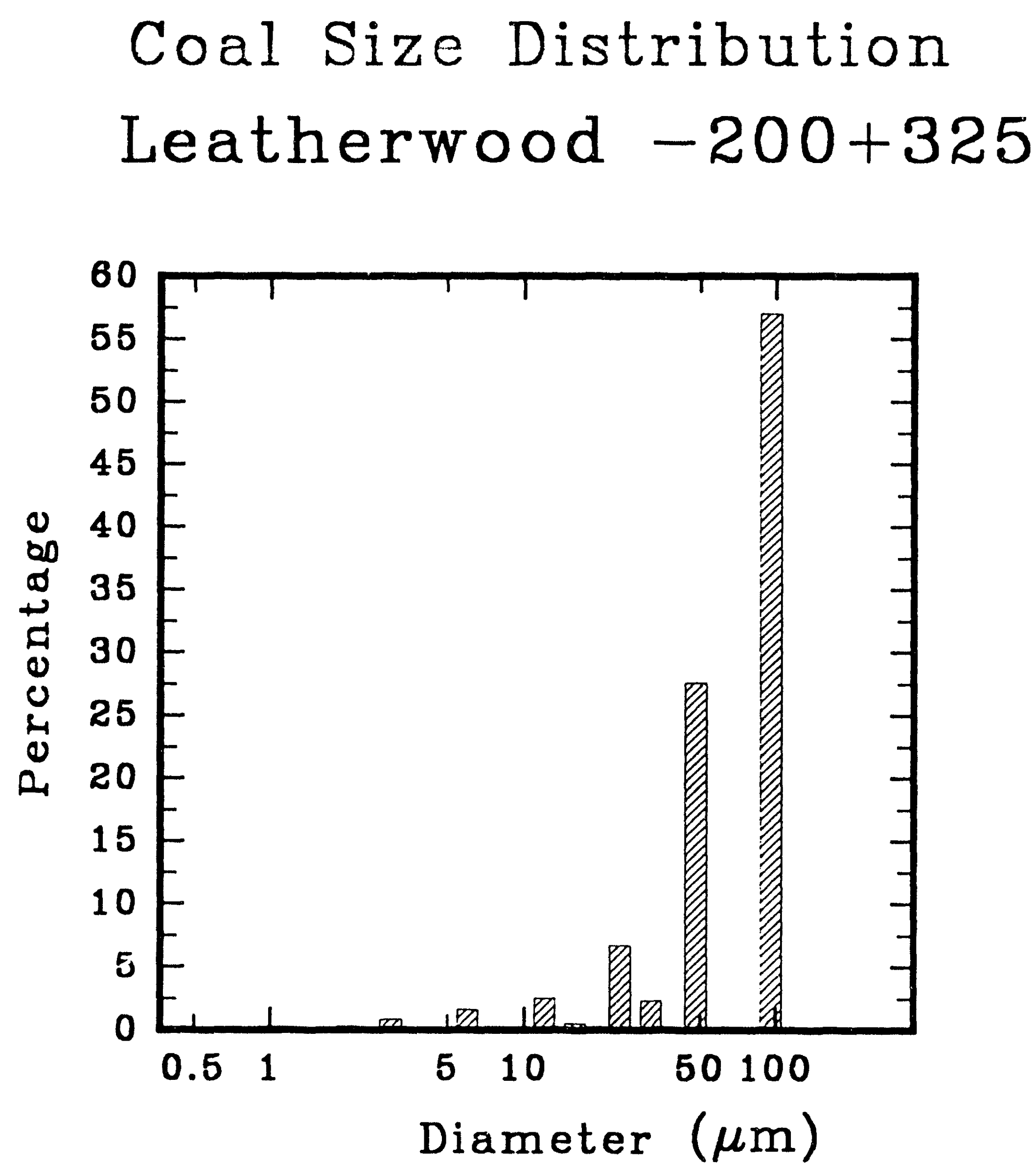
3. System improvements

A new feed system enclosure tank was designed and constructed to simplify the particle loading and feeding. The new tank is constructed of stainless steel and designed to operate under slight positive pressures.

When evaluating finer sized particle charge, it was noted that the particle mass was not sufficient to overcome the electrolyte surface tension. As a result, instead of submerging in the electrolyte and fully releasing their charge, the particles would tend to sit on top of the liquid. To address this problem, the electrolytic solution was placed in an ultrasonic vibration bath and a surfactant was added.

## Task 4. Reports/Publications

John L. Schaefer, Heng Ban, John Stencel, "An Overview of Fine Coal Cleaning Research at the CAER", Processing and Utilization of High Sulfur Coals V Conference, October 25-28, 1993, Lexington, KY..



Coal Size Distribution
Leatherwood -200+325
60
55
50
45
40
35
30
25
20
15
10
5
0
Percentage
0.5
1
5
10
50
100
Diameter (μm)


Figure 1

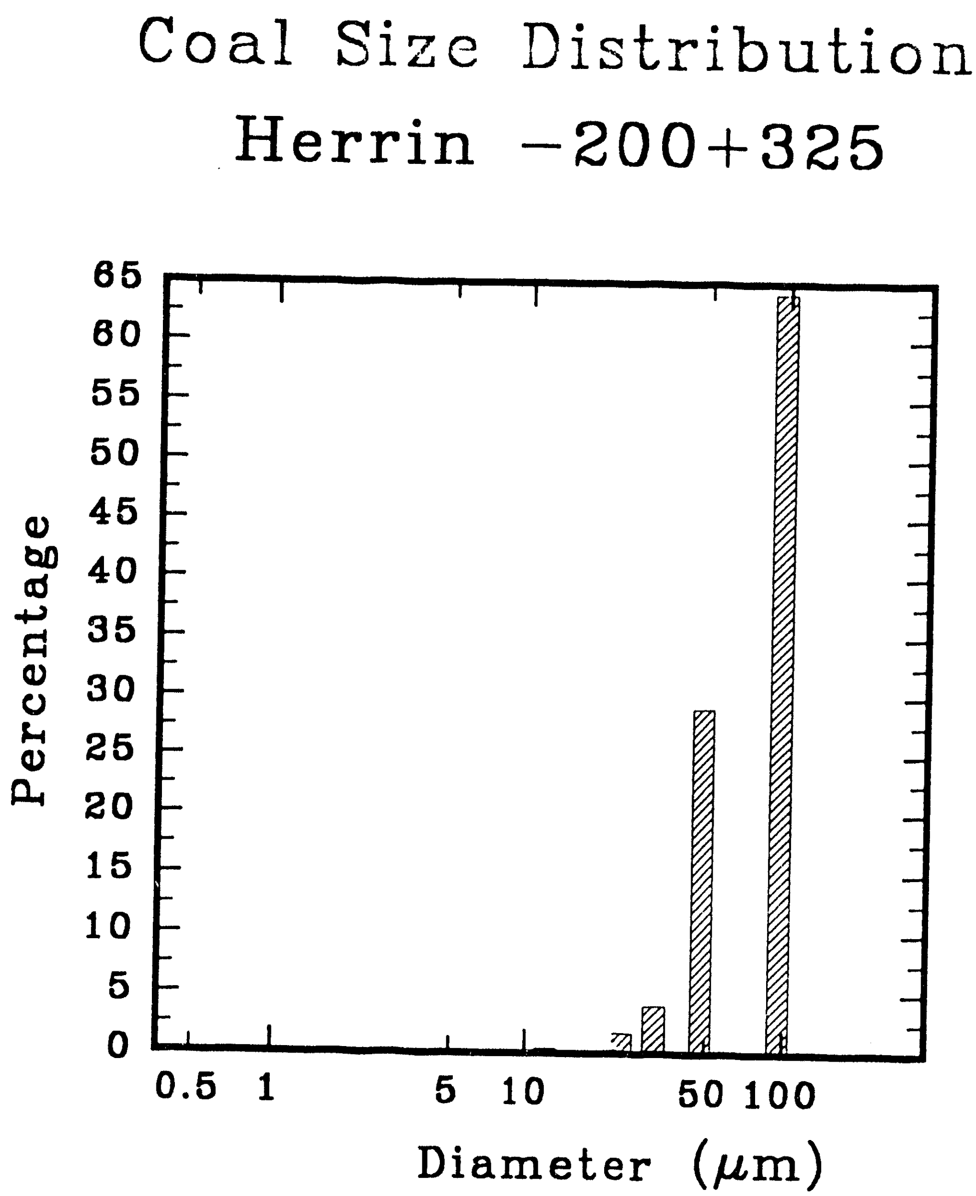
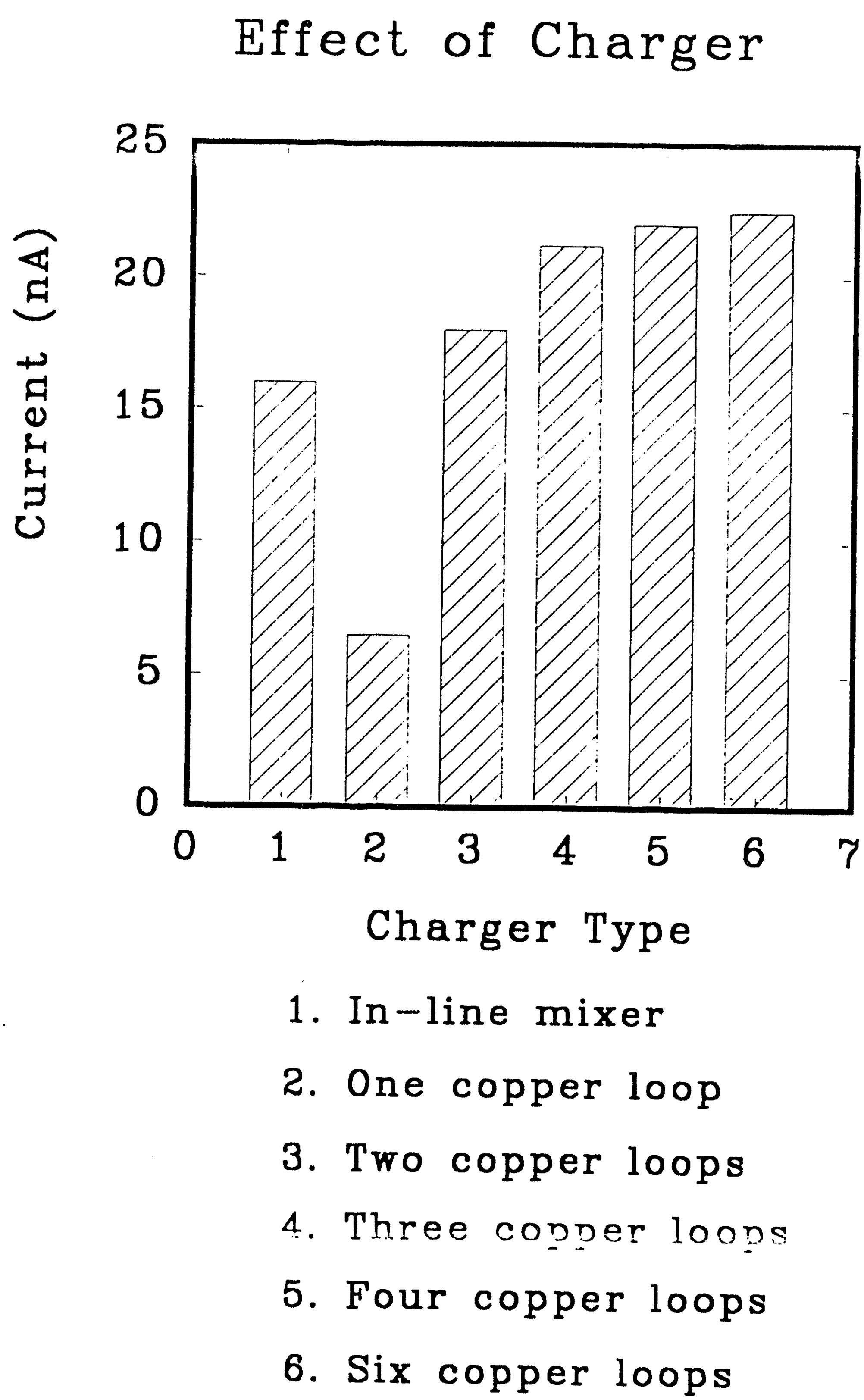

Coal Size Distribution
Herrin −200+325
Percentage
0
5
10
15
20
25
30
35
40
45
50
55
60
65
0.5
1
5
10
50
100
Diameter (μm)

Figure 2



Effect of Charger
Current (nA)
25
20
15
10
5
0
0
1
2
3
4
5
6
7
Charger Type
1. In-line mixer
2. One copper loop
3. Two copper loops
4. Three copper loops
5. Four copper loops
6. Six copper loops


Figure 3

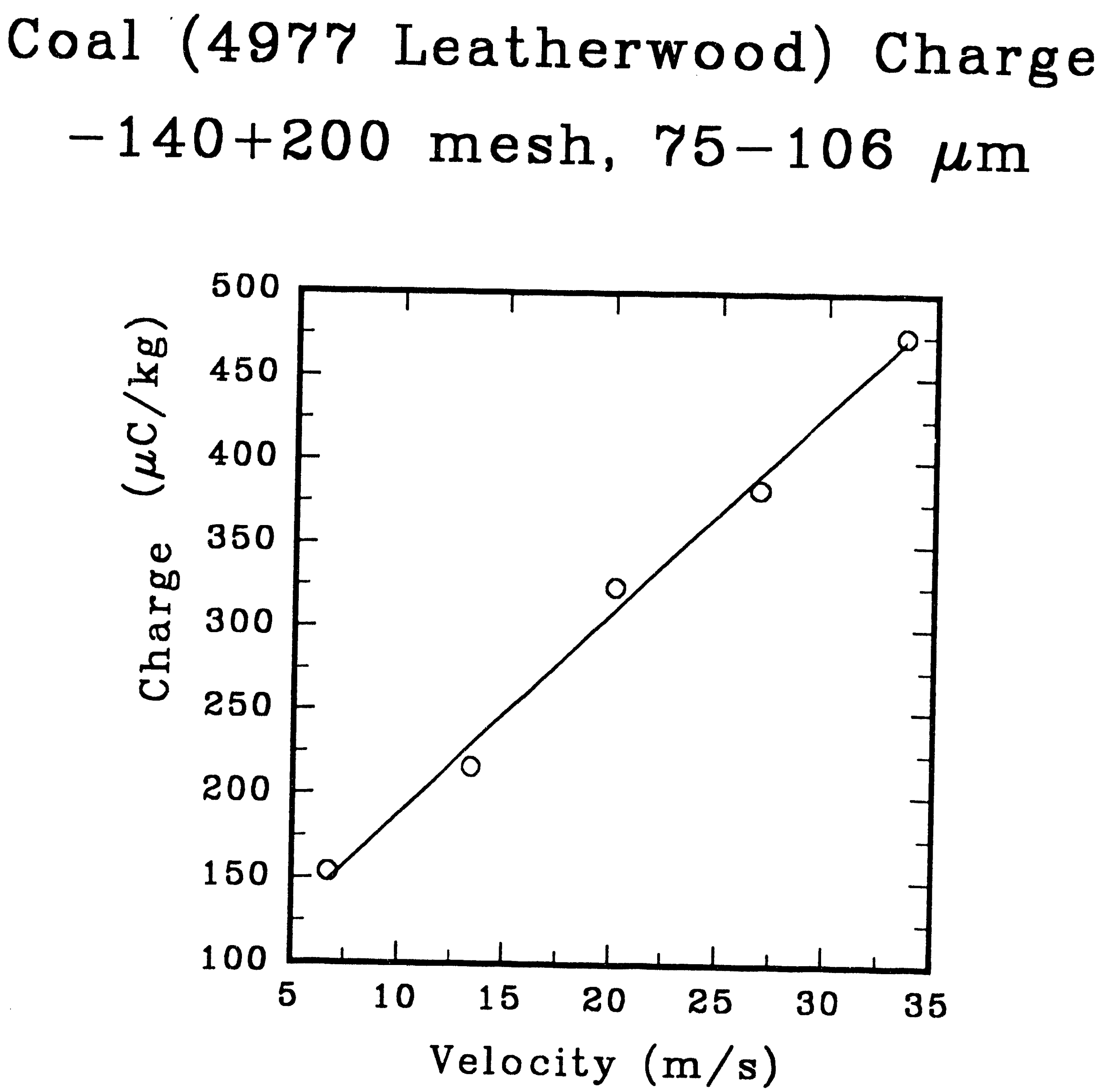

Coal (4977 Leatherwood) Charge
−140+200 mesh, 75−106 μm
Charge (μC/kg)
500
450
400
350
300
250
200
150
100
5
10
15
20
25
30
35
Velocity (m/s)

Figure 4

# Coal (8377 Herrin) Charge
## −140+200 mesh, 75−106 μm

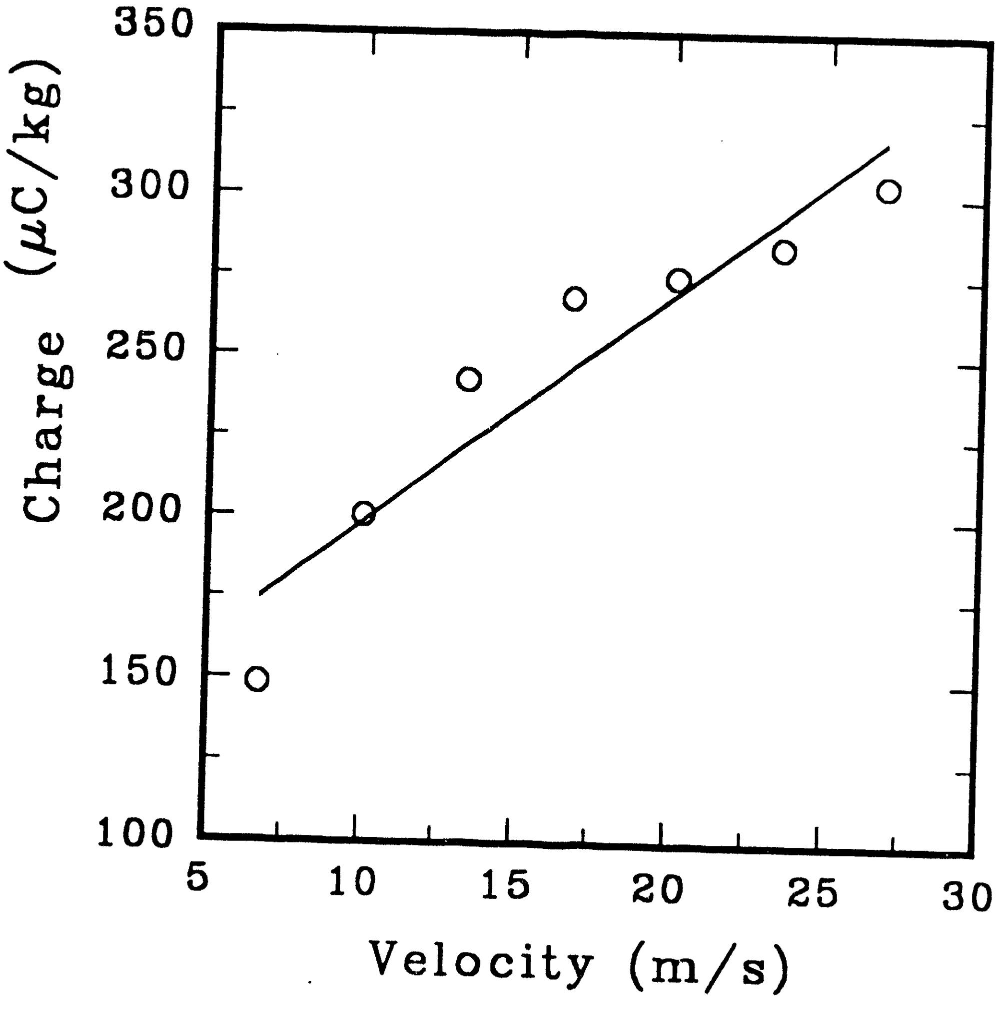



**Figure 5**

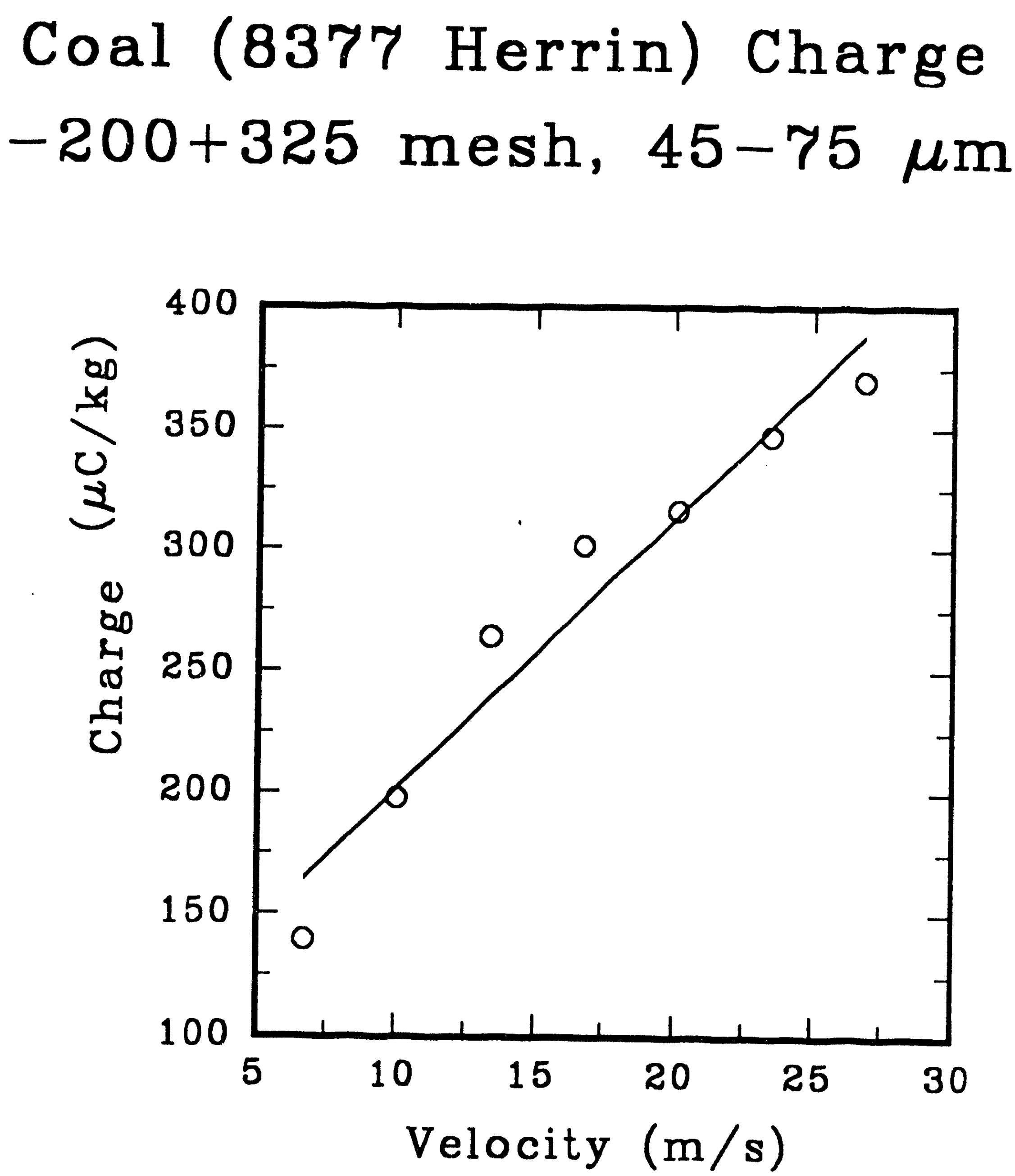

Coal (8377 Herrin) Charge
−200+325 mesh, 45−75 μm
Charge (μC/kg)
400
350
300
250
200
150
100
5
10
15
20
25
30
Velocity (m/s)

Figure 6

# Glassy Carbon Charge
# −200+325 mesh, 45−75 μm

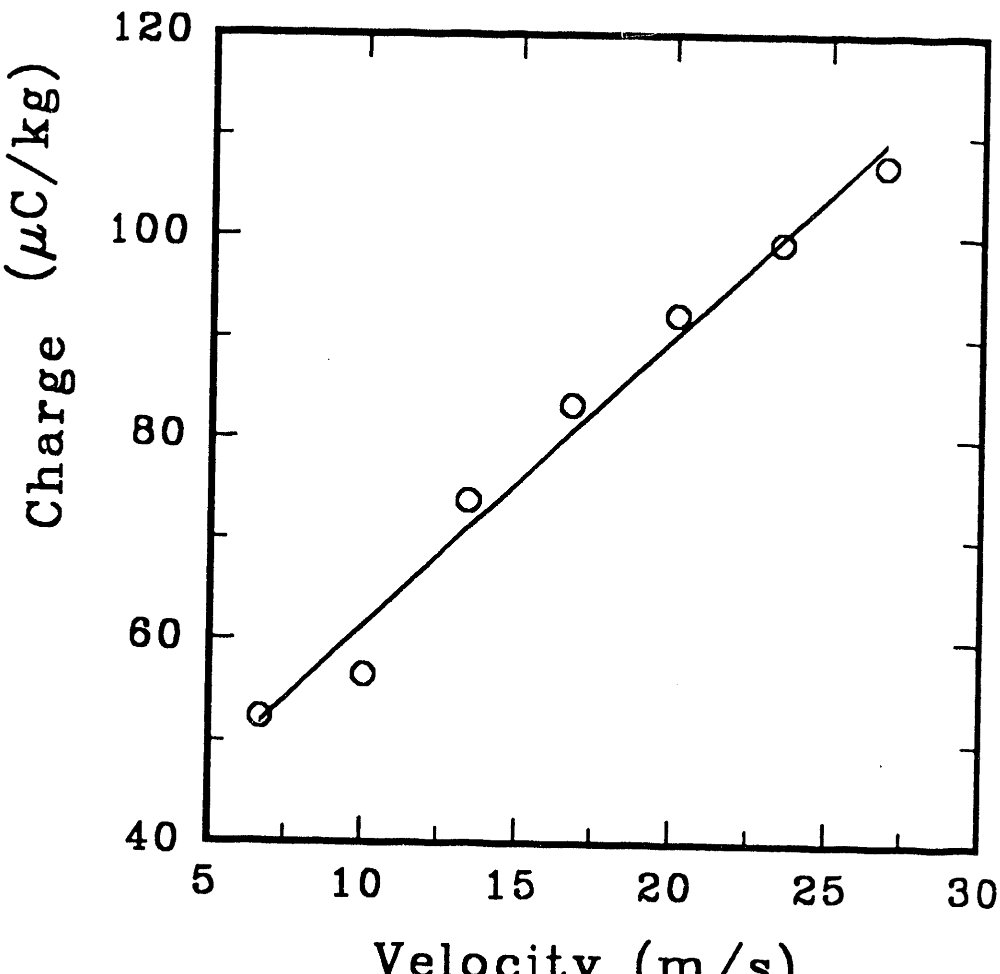



**Figure 7**

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5/23/94

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