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## RESEARCH NOTE 19

TECHNIQUES FOR PRODUCING SUBMICRON-SIZE  
PLASTIC PARTICLES

by I. R. Tannenbaum

HELIODYNE CORPORATION  
Los Angeles, California 90064

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## ABSTRACT

A brief review of powder technology is presented, covering aspects of interest to the SAPAG project. Included in this portion is a discussion of the methods of producing finely divided powders and the possible mechanisms involved in agglomeration. The techniques used in the production of fine powders for use in the SAPAG experiment are described and representative micrographs of powder preparations, as well as number density distributions, are presented and discussed.

TABLE OF CONTENTS

Section		Page
	ABSTRACT .....	i
1.	REVIEW OF POWDER TECHNOLOGY .....	1
2.	COMMINUTION OF MATERIALS FOR USE IN THE SAPAG EXPERIMENT .....	7
	REFERENCES .....	25

## 1. REVIEW OF POWDER TECHNOLOGY

Mechanical disintegration of solid substances may be brought about by either of two methods: the relatively slow application of shearing and tensile stresses or by the application of a crushing pressure. An example of the former technique may be found in milling processes while the latter type of comminution is demonstrated by roller mills or by the use of impact instruments.

The ultimate size of particles produced by any method seems to be limited by the nature of the material being treated and by the equipment used. When a substance is treated in a comminutor the mean particle size initially decreases with time. As the period of treatment is extended, the changes observed in the particle size distribution become progressively smaller and eventually the distribution appears to stabilize. In some cases, continued comminution can actually cause an increase in the mean particle dimension. No definitive study of the physics of the processes involved in the production of ultrafine powders has been made, although some investigators<sup>1, 2</sup> believe that, as the particles become progressively smaller, a dynamic equilibrium is attained wherein the smaller particles in the distribution recombine as rapidly as they are produced.

Generally, finely divided powders form aggregates. The physical forces causing this aggregation can be attributed partially to the existence of van der Waals forces acting between the particles. These forces, although weak when computed per molecule, can be

appreciable when acting through a relatively small distance between microscopic particles containing large numbers of molecules. Accordingly, the attractive force between two spherical particles has been calculated<sup>3,4</sup> by integration of the van der Waals forces over all pairs of molecules. These investigators found that, subject to their restrictions, the attractive force would vary directly as the harmonic mean of the particle diameters and inversely as the square of the interparticulate separation. Similar calculations for other than spherical particles have more recently been made<sup>5</sup> and are in substantial agreement with those previously obtained. For spherical particles one-half micron in diameter, separated by  $5\text{\AA}$ , the interparticulate attractive force is in the neighborhood of  $10^{-4}$  dyne. This attractive force must be considered as being correct only to within an order of magnitude since the presence of irregular shapes has not been considered nor has the irregularity of the particle surface on a molecular scale. Furthermore, the presence of clean, dry surfaces consisting only of the pure material is very difficult to obtain in practice.

The deleterious effect exhibited by only a monolayer of water on the surface of the particles has been demonstrated conclusively by an experiment<sup>6</sup> in which the investigator coated the particles with a layer of hydrophilic material one or two atoms thick. The result of this treatment was to reduce materially the formulation of multi-particulate agglomerates.

Another major factor which has been noted to cause particle agglomeration is the presence of electrical charges. Clearly, the larger the particle, the larger the possible electrical charge. Since

charge densities ranging about a few electron charges per square micron are common, the charge on a 0.5 micron particle could well be of the order of an electron charge unit so that the electrostatic attractive force could well be considerably greater than that due to the van der Waals forces<sup>7</sup>. This type of attractive force can be generated by friction whenever the finely divided material moves relative to another medium.

An additional effect of motion of the particulate matter through a gas also further increases the agglomeration rate and the loss of particles from suspension. This is the increase in the number of interparticle collisions and also the number of particle-wall collisions. Experimental results<sup>8</sup> show a very marked dependence of settling rate of a smoke on the average speed of suspending gas motion. The increase in the settling rate has been closely related theoretically to agglomeration due to the increased frequency of collisions and also to the collisions with the wall, the sticking factor for which seems to be very close to unity.

There are basically two distinct types of electrical charging possible, both of which seem to lead to an increase in agglomeration and settling of a suspended finely divided powder. Whether the particles are charged in a unipolar mode or bipolar mode, the results are the same, viz., the dispersion generally is made less stable, although the mechanism in the two cases differs. The effect of bipolar charging of the particles can intuitively be expected to result in an increase in the agglomeration rate and both experiment and theory confirm such intuition, as has recently been summarized in a comprehensive review article<sup>9</sup>.

The effect of unipolar charging is not too clearly understood, the experimental evidence being contradictory<sup>10, 11</sup>; however, a recent analysis of the data<sup>12</sup> indicate that the increase in the diminution of the particle concentration is so small that the early investigations were not sufficiently sensitive to permit detection. The mechanisms currently thought to be responsible for unipolar-induced particle concentration decrease are the mutual induction of a charge of opposite polarity by particles in close proximity which can overcome the repulsive Coulombic force operating at greater distances and the Coulombic attraction to the walls. The latter mechanism is effective since unipolar charging can occur only when the walls of the container acquire a charge opposite to that of the suspended particles.

An additional process which causes the destabilization of aerosols is agglomeration caused by the presence of an acoustic field. Direct experimental evidence of the degeneration of aerosols has been observed by many workers<sup>13, 14, 15</sup> to be caused by both sonic and ultrasonic frequencies. Using sonic waves with a frequency of 10 kc/sec for 5 sec Brandt and Freund<sup>15</sup> found that the average particle diameter increased by a factor, varying with intensity, which ranged up to 10 when the initial particle size was 1.8  $\mu$ . Attendant upon this particle size increase was an accompanying increase in the sedimentation rate by a factor of 30.

No quantitative explanation of the mechanism of sonic precipitation of aerosols has been developed although the vibration of the particles with the gas, hydrodynamic forces between neighboring particles, and the radiation pressure caused by a sound field of

plane stationary waves have all been studied with respect to this problem. However, the magnitude of the increase in agglomeration and sedimentation rates is much larger than can be predicted on the basis of these three possible mechanisms. The motion of a particle relative to that of the gas in which it is embedded is a function of particle size and acoustic frequency for a given material and suspending gas. In the range of particle size from a few tenths of a micron to 2 microns, the lag in the particulate motion becomes appreciable as the sonic frequency goes from 100 cps to 10 kc/sec. Hence, it is difficult to explain the rapid agglomeration upon the basis of increased collision frequency. Furthermore, such a mechanism could explain an increase in the collision frequency only for those particles having their line of centers in the direction of the acoustic vibration and within the range of effectiveness, which would be the amplitude of vibration. Clearly, this mechanism cannot explain the very rapid increase in sedimentation and agglomeration.

Bernoulli forces, acting perpendicular to the direction of vibration, similarly, cannot be expected to be of such magnitude as to explain the very large observed effect and this has been borne out by calculation<sup>16</sup>.

The radiation pressure, likewise, cannot explain the observed behavior since this effect leads to concentration increases at the nodes of factors of the order of 2-3 for particles of 1  $\mu$  diameter in a sound energy field with energy density  $10^3$  ergs/cm<sup>3</sup> in forty seconds while the agglomeration rate increases by a factor of 20 under the same conditions<sup>17</sup>.

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## 2. COMMINATION OF MATERIALS FOR USE IN THE SAPAG EXPERIMENT

The preparation of ultrafine powders required for use in the SAPAG experiment has been carried out both at room temperature and at cryogenic temperatures. Room temperature comminution has been successful for the more brittle materials studied while the more rubbery substances require low temperature conditions before the appreciable production of fine particles takes place.

In all cases, the polymeric materials were found to be sensitive to the presence of moisture in the atmosphere in that the inability to produce the ultrafine particles was noted in all attempts to comminute in the presence of moisture. A well controlled, dry atmosphere is required in order to prevent the formation of large aggregates, or, in some cases, to permit the formation of the fine particles.

Three instruments have been designed and constructed in order to produce the powder required by the experiment. A cryogenic ball mill, constructed of stainless steel and using stainless steel balls as impactors is capable of producing approximately 20 grams of submicron sized powders per day. The ball chamber of this mill is machined smooth and has no sharp corners so that cleaning is easily accomplished to minimize the level of contamination between successive loadings of different materials. The grinding chamber is hermetically sealed and is opened only in a controlled atmosphere so that the powders produced are kept free of contamination due to absorbed gases. The cryogenic ball mill can be refrigerated by continuous immersion of the lower portion of the grinding

chamber in an insulated container of liquid nitrogen. In order to facilitate heat transfer, copper cooling fins circle the periphery of the ball chamber.

The remaining devices used for the production of ultrafine powders are basically the same type of instrument, one merely being a scaled-up version of the other. Both utilize simple harmonic motion of the grinding chamber to deliver the energy required by the material for comminution. The prototype version of the high energy harmonic impactor is limited to the production of only approximately four grams of comminuted material per day due to its small size. The scaled-up version, however, should permit economical production of fine powders since the production rate for this instrument is expected to be of the order of 40 grams per day.

The prototype harmonic impactor is particularly useful in the development stages of the production of fine powders of new materials primarily because of its small size. This permits the production of a small quantity of powder to be completed entirely within a dry box. Furthermore, all materials studied in this instrument to date have been reduced to sub-micron-sized particles in less than 20 minutes, so that a rapid assessment of the possible degree of comminution of a given material is possible.

The operation of these impactors depends upon the acceleration of attritors within a crucible containing small chunks of material to be powdered. The attritors can either be steel balls or can be large particles of material undergoing comminution. When the material being ground has sufficient structural strength, the crucible can be machined from the same material so that contamination of

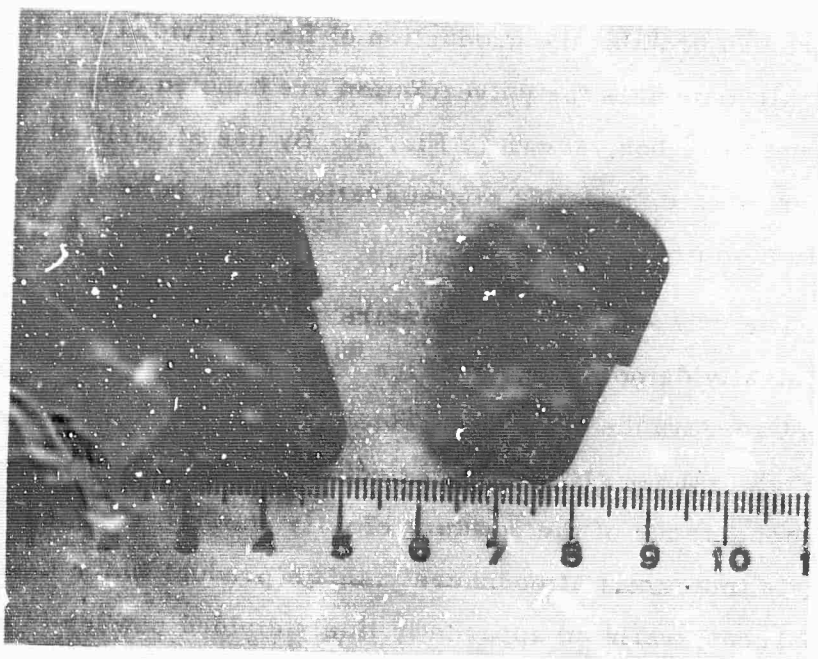
the powders by the crucible and the attritors can be reduced to zero from the very low value observed when steel is utilized in these applications. Figure 1 illustrates self-crucibles which have been used in the harmonic impactor.

As discussed in the preceding section, the presence of moisture can prohibit the production of finely divided powders. Hence, all materials for pulverization are handled only in an inert atmosphere dry box, shown in Fig. 2. By use of purified nitrogen in this enclosure, possible contamination of the powders by other gases is also precluded.

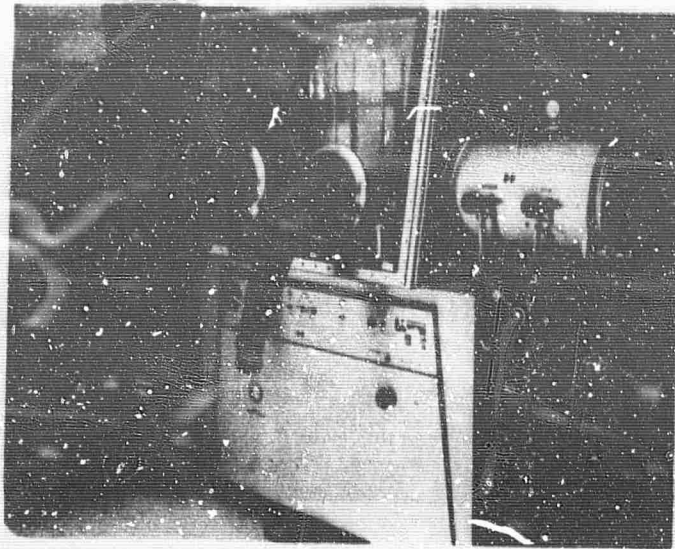
The marked effect of moisture upon finely divided materials is graphically demonstrated in Figs. 3 and 4, in which the totally different appearance of powders obtained by dry comminution are contrasted to those obtained by grinding in room air. The macroscopic appearance of the powders clearly shows that processing of materials in a moist atmosphere yields a product which agglomerates markedly while an apparently finely divided powder is obtained by controlling the atmosphere.

Figure 4 shows optical photomicrographs of the powder shown macroscopically in Fig. 3. It is easily seen that dry grinding produces a much smaller average particle size than does the same procedure in the presence of moisture.

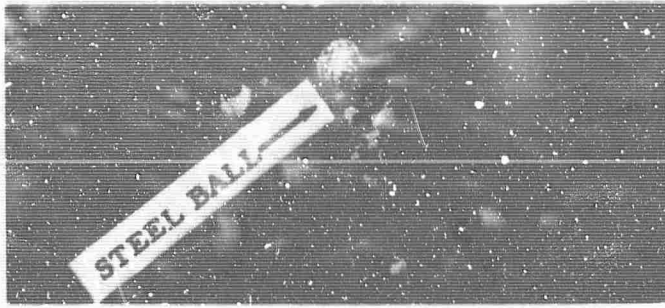
The presence of two phases in the bulk material can lead to differential grinding. Figures 5 and 6 illustrate this effect by means of optical photomicrographs of a fiber glass filled phenolic graphite after treatments of one minute and 20 minutes, respectively, in the harmonic impactor. The presence of the fiber glass phase is clearly



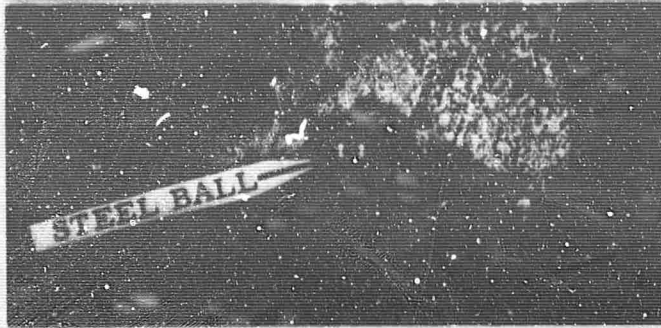
**Fig. 1** Self-crucibles machined from bulk materials to prevent the possibility of contamination of fine powders by the comminution container. Crucible on left is an epoxy, and that on the right is a phenolic graphite.



**Fig. 2** Inert atmosphere dry box which is used to minimize contamination of fine powders. The gas used in the dry box is nitrogen from which the oxygen is removed by catalytic reaction with hydrogen, and water vapor is removed by adsorption on a molecular sieve. The typical level of contamination in this dry box is less than 3 ppm water as read on an electrolytic moisture detector. The oxygen level is sufficiently low that a tungsten filament bulb can be maintained incandescent for days unprotected without failure.



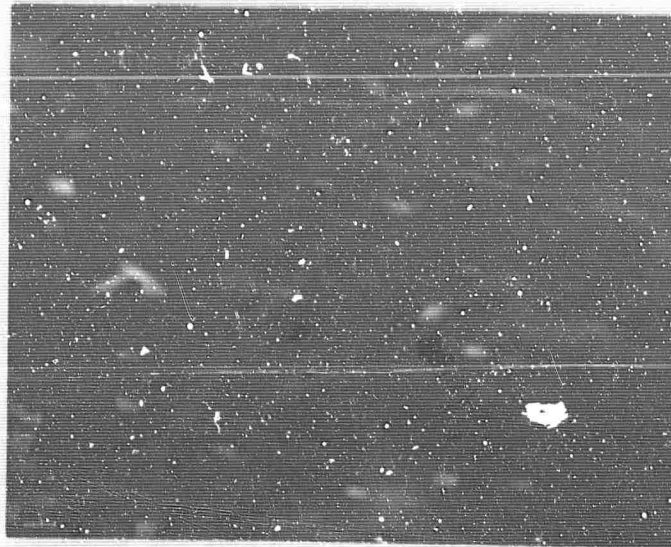
View A



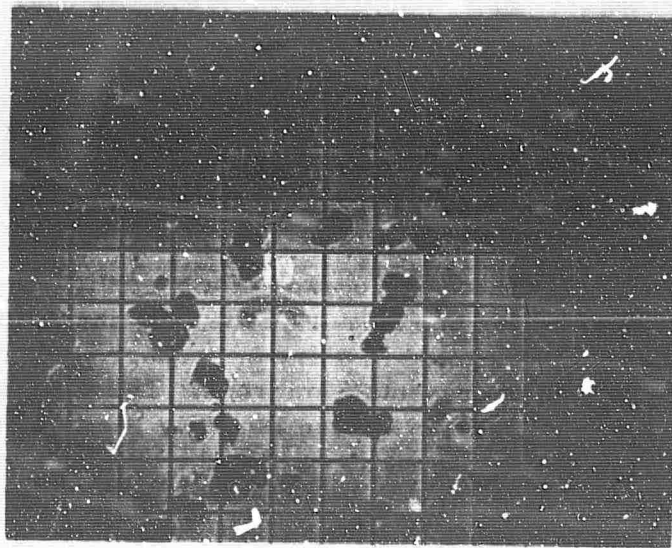
View B

**Fig. 3** Results of comminution of Avcoat II in the high energy harmonic impactor. View A shows the material after being ground in room air. Note that the steel ball used for the comminution is covered by an adherent mass of ground material.

View B shows the results of the comminution of the same material in the same equipment, the only change from the above being the replacement of moist air with an inert dry atmosphere. In this case the powder shows no tendency to stick to the ball or to form large agglomerates.

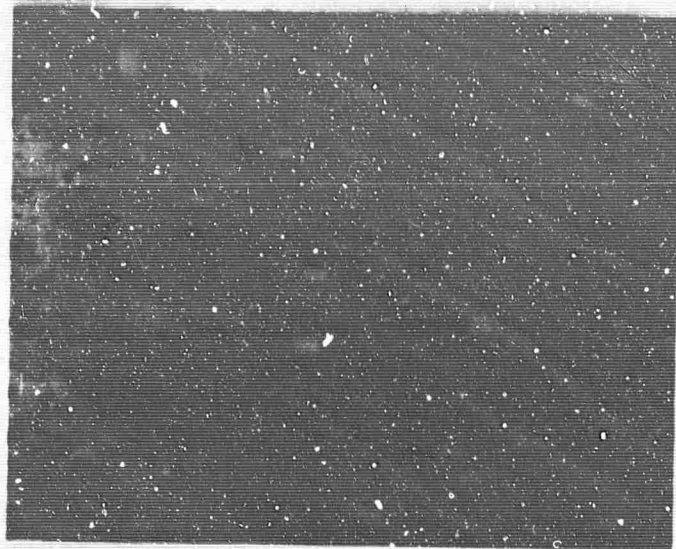


View A



View B

**Fig. 4** Optical photomicrographs of Avcoat II after comminution in the high energy impactor. Each square represents 5 microns. The photomicrograph in view A, of moist material, shows the presence of large agglomerates. The photomicrograph in view B, of dry material, shows the presence of relatively small particles and the complete absence of the very large agglomerates of the moist material.



**Fig. 5** Optical photomicrograph of a phenolic graphite treated for one minute in the high energy harmonic impactor in a dry atmosphere. Each square represents 5 microns. The presence of the fiberglass phase is easily seen as the rod that runs diagonally across the photomicrograph.

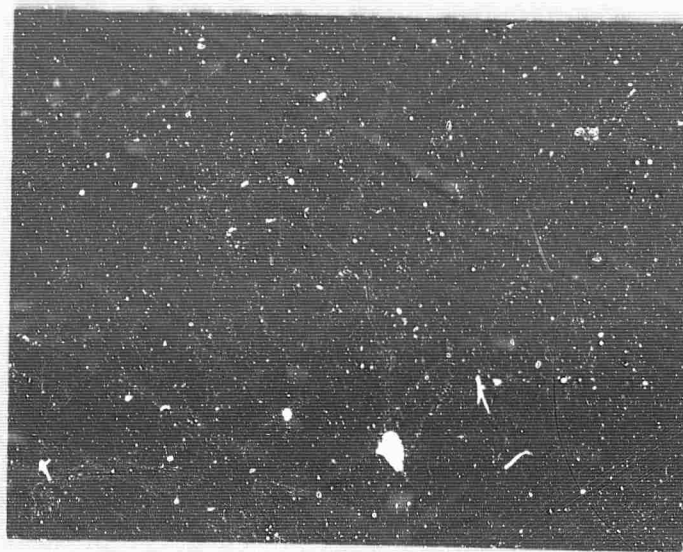


Fig. 6 Optical photomicrograph of phenolic graphite after 20 minutes in the high energy harmonic impactor in a dry atmosphere. Each square represents 11 microns. Both phases have been comminuted to the limit of detection by optical microscopy.

seen after one minute of grinding but after the additional 19 minutes the powder appears to be homogeneous within the limit of detection by optical microscopy. An electron micrograph of the same material is shown in Fig. 7 in which the actual size of the particles produced can be seen as well as the presence of two phases.

Using randomly sampled electron micrographs, statistical analyses of the finely divided powders can be prepared. A typical analysis is presented for the sample which is shown in Figs. 6 and 7. The results on a count of some 800 particles are shown in Table I and are plotted in Figs. 8 and 9. Two phases are easily discernible, the large non-transparent material and the smaller, transparent phase, arising from the glass and phenolic phases, respectively. Visual inspection of this sample in the electron microscope shows that the small semi-transparent phase consists of platelets with a relatively uniform thickness of approximately 400 Å while the larger, opaque particles have thicknesses on the order of their diameters.

Some of the materials treated seem to comminute but tend to form loose aggregates by virtue of the small interparticulate separation of a "condensed" powder phase. Characteristic electron micrographs of an epoxy resin treated for 72 hours at room temperature in the cryogenic ball mill are presented in Figs. 10 and 11. The presence of particulate matter with major dimension of  $0.2 \mu$  is shown to be present with an average particle size of approximately  $0.5 \mu$ . The loose agglomeration of the small particles to form larger, often circular, groupings is seen here.

The possibility of contamination arising from grinding in a steel apparatus has been studied by the spectroscopic determination



Fig. 7 Electron micrograph of glass-filled phenolic graphite at a magnification of 22000X. The very small particle size is shown, as is the presence of two phases. The statistical particle size analysis based upon this photograph and eleven others is presented in Fig. 8 and 9.

TABLE I  
PARTICLE SIZE ANALYSIS FOR PHENOLIC GRAPHITE

Particle Size $\mu$	Small Particles		Large Particles		Total Particles	
	Increment of Count (%)	% Greater Than	Increment of Count (%)	% Greater Than	Increment of Count (%)	% Greater Than
0.08-0.1	24.02	75.98	14.52	98.54	21.44	78.56
0.1-0.2	20.42	55.56	22.58	62.90	21.01	57.55
0.2-0.3	20.42	35.14	13.71	49.19	18.60	38.95
0.3-0.4	13.81	21.33	6.45	42.74	11.82	27.13
0.4-0.5	7.51	13.82	7.26	35.48	7.44	19.69
0.5-0.6	9.31	4.51	9.68	25.80	9.41	10.28
0.6-0.7	2.40	2.11	8.06	17.74	3.94	6.34
0.7-0.8	1.20	0.91	8.11	16.93	1.09	5.25
0.8-0.9	0.30	0.61	6.45	10.48	1.97	3.28
0.9-1.0	0.60	0	2.42	8.06	1.09	2.19
1-2			4.84	3.22	1.31	0.88
2-3			2.42	0.80	0.66	0.22
3-4			0.81	0	0.22	0

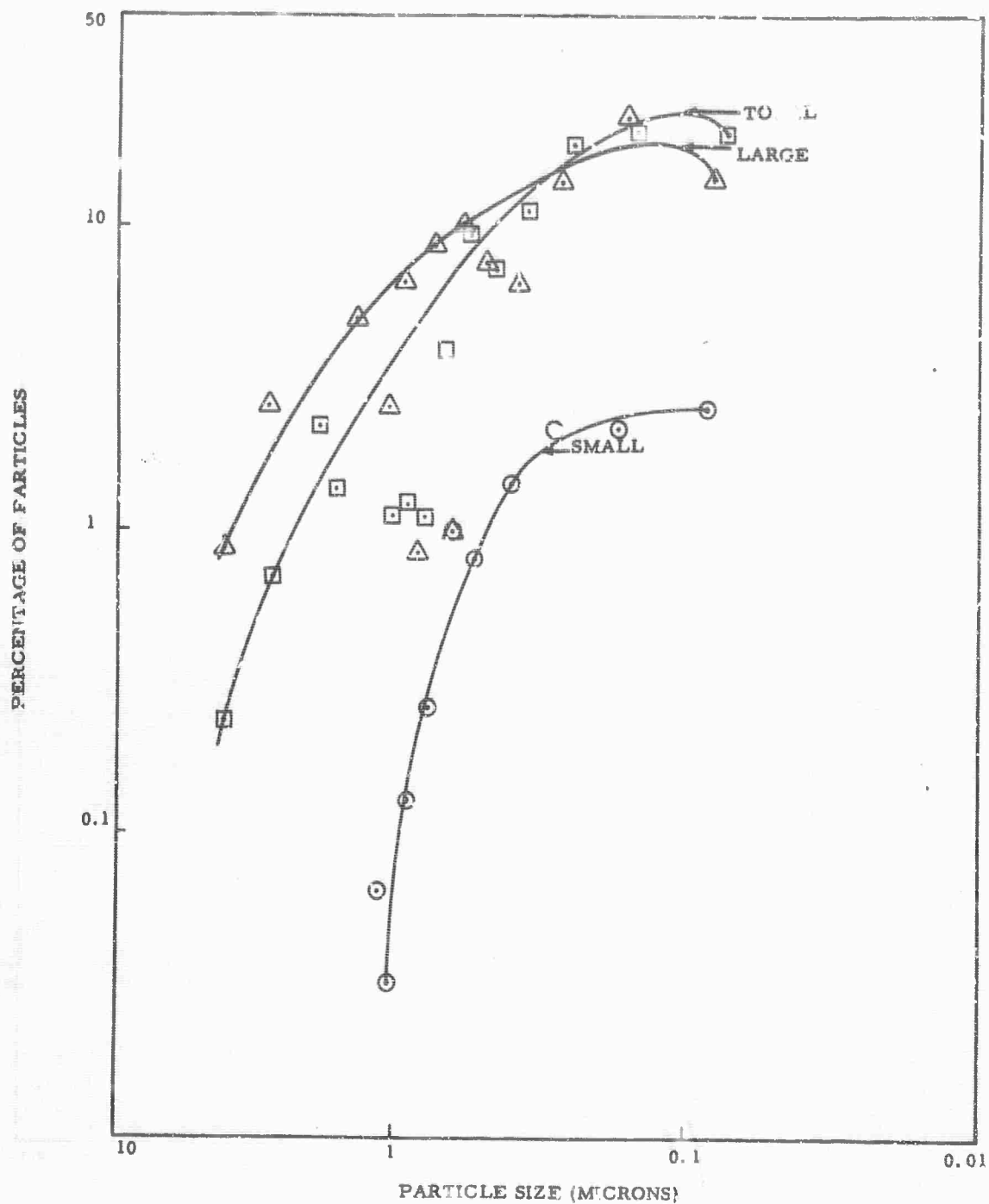


Fig. 8 Particle size analysis for phenolic graphite. This differential distribution curve for material shown in Figure 7 is obtained by counting all the particles on 13 electron micrographs. Note the presence of large amounts of particles in the submicron range.

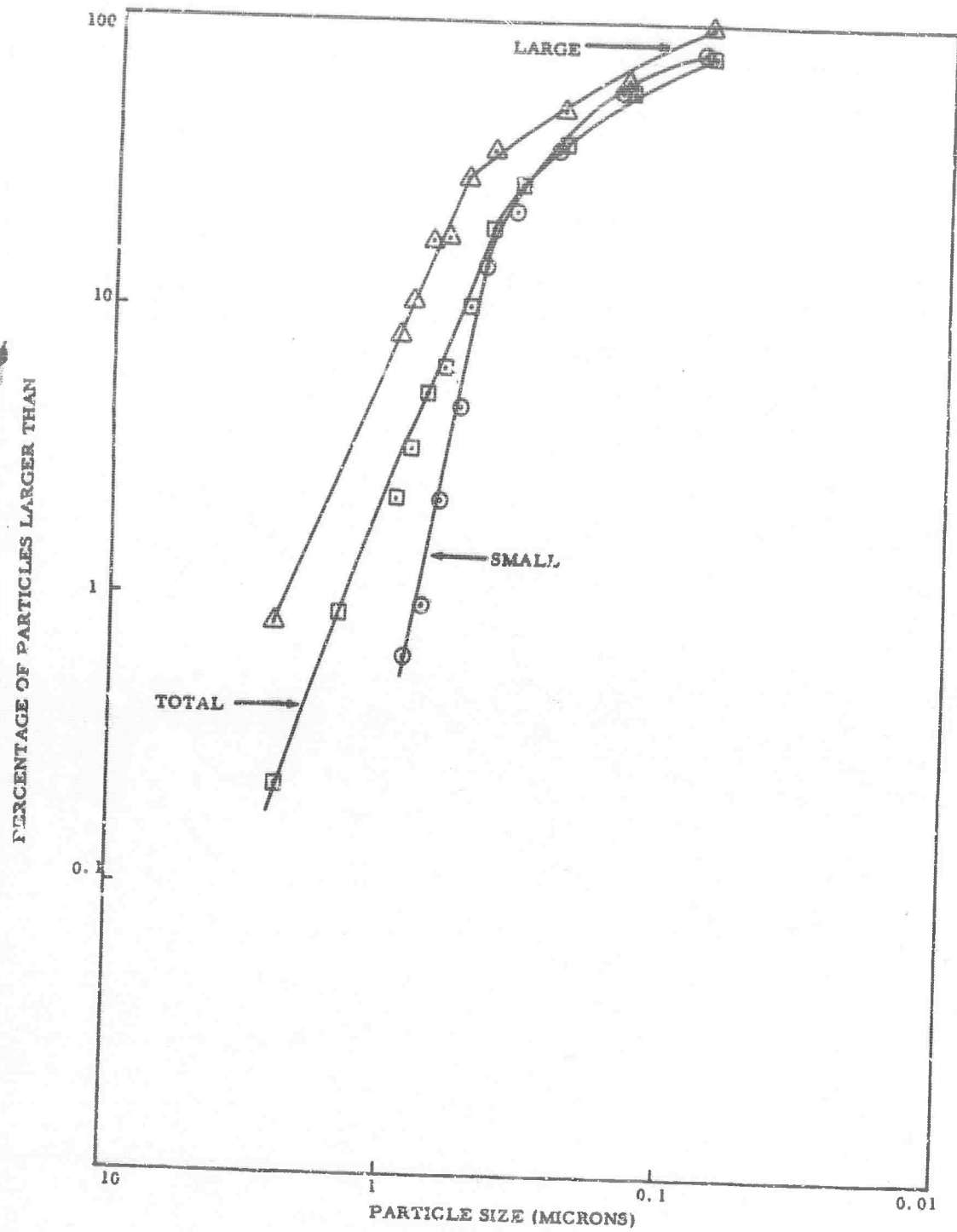
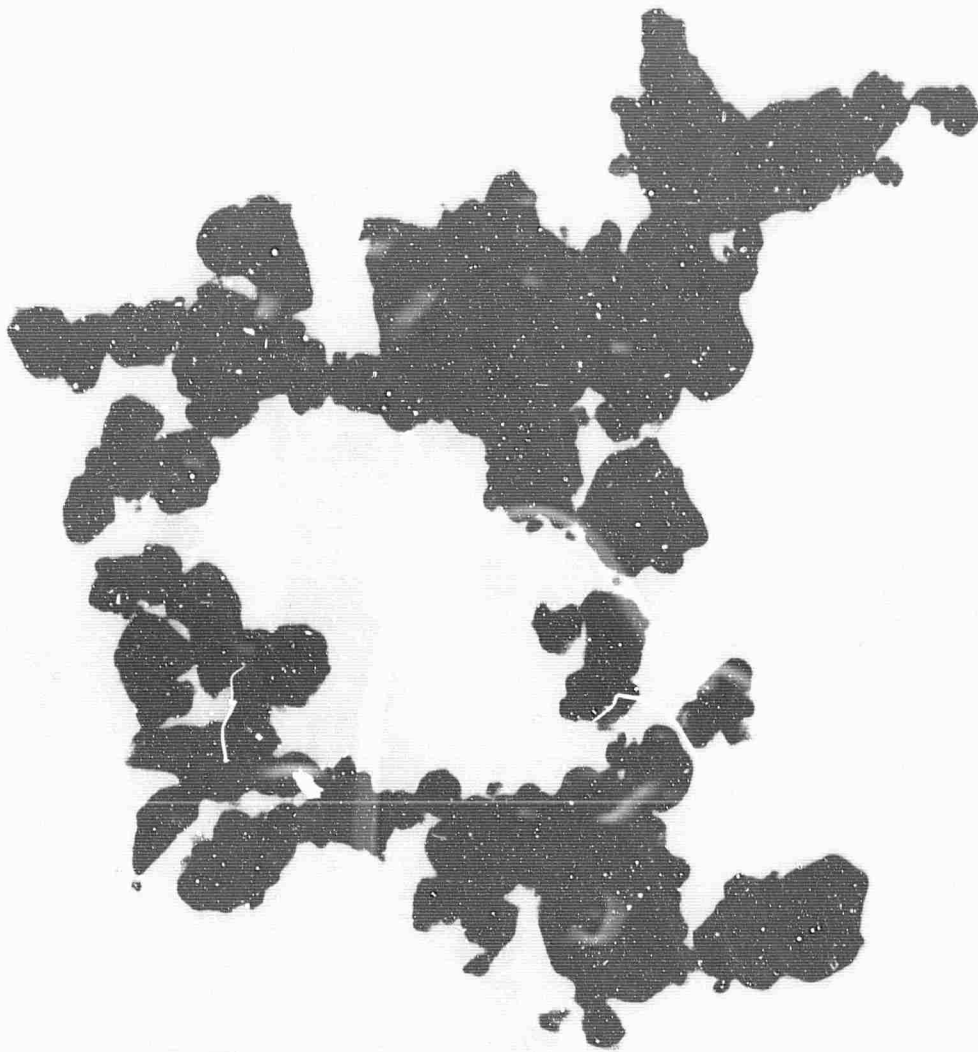


Fig. 9 Particle size analysis for phenolic graphite. This integral distribution curve for material shown in Figure 7 is obtained from the data plotted in Figure 8.



Fig. 10 Electron micrograph of an epoxy resin comminuted 72 hours at room temperature in the cryogenic ball mill (magnification is 15000X). The presence of small particles (0.2 microns) is shown. Similarly, the loose agglomeration of the small particles can be seen in this micrograph.



1 micron



Fig. 11 Electron micrograph of an epoxy resin comminuted 72 hours at room temperature in the cryogenic ball mill (magnification is 15000X). The presence of small particles (0.2 microns) is shown. Similarly, the loose agglomeration of the small particles can be seen in this micrograph.





of the presence of metallic elements before and after treatment. Although the level of contamination seems to increase after a 72 hour ball milling, the increase is comparable to the very small amount present initially (typically, e.g., for iron from 1.9 ppm to 3.1 ppm) so that the increase in the level of contamination, if real, is very small on an absolute scale.



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#### REFERENCES

1. Bradshaw, B.C., *J. Chem. Phys.* 19, 1057 (1951).
2. Bowden, F.P., and Tabor, D., *Friction and Lubrication of Solids*, Oxford University Press, London (1950).
3. Bradley, R.S., *Phil. Mag.* 13, 853 (1932).
4. Hamaker, H.C., *Physica*, 4, 1058 (1937).
5. Vold, M.J., *J. Colloid Sci.* 9, 451 (1954).
6. Lane, W.R., *Powders in Industry*, S.C.I. Monograph 14, pp 164 ff., Society of Chemical Industry, London (1961).
7. Beischer, D., *Kolloid-Z.* 89, 215 (1939).
8. Langstroth, G.O., and Gillespie, T., *Can. J. Res.*, 25B, 455 (1947).
9. Gillespie, T., *Int. J. Air Poll.* 3, 44 (1960).
10. Jander, G., and Winkel, A., *Kolloid-Z.* 63, 5 (1933).
11. Fuchs, N., and Petrjanov, I., *Acta Physicochim. URSS*, 3, 827 (1935).
12. Green, H.L., and Lane, W.R., *Particulate Clouds: Dusts, Smokes, and Mists*, p 164, D. Van Nostrand Company, Inc., Princeton (1964).
13. St. Clair, H.W., U.S. Bur. Mines, R.I. 3400 (1938).
14. Patterson, H.S., and Cawood, W., *Nature*, 126, 667 (1931).
15. Brandt, O., and Freund, H., *Z. Physik*, 92, 385 (1934); *ibid.*, 94, 348 (1935).

16. Brandt, O., Freund, H., and Hiedemann, E., Z. Physik, 104, 511 (1937).
17. St. Clair, H. W., Spendlove, M. J., and Potter, E. V., U.S. Bur. Mines, R. I. 4218 (1948).

<p>Heliodyne Corporation, Los Angeles, California 90064  <b>TECHNIQUES FOR PRODUCING SUBMICRON-SIZE PLASTIC PARTICLES</b>, by I. R. Tannenbaum. June 1965. 27 p. Incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 19) (Contract No. DA 04-495-AMC-458(Z))</p> <p>Unclassified Report</p> <p>A brief review of powder technology is presented, covering aspects of interest to the SAPAG project. Included in this portion is a discussion of the methods of producing finely divided powders and the possible mechanisms involved in agglomeration. The techniques used in the production of fine powders for use in the SAPAG experiment are described and representative micrographs of powder preparations, as well as number density distributions, are presented and discussed.</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> <li>1. Submicron particle production</li> <li>2. Agglomeration</li> <li>3. Particle size distribution</li> </ol> <ol style="list-style-type: none"> <li>I. Tannenbaum, I. R.</li> <li>II. Heliodyne Corporation Research</li> <li>III. Note 19</li> <li>IV. Contract No. DA 04-495-AMC-458(Z)</li> </ol>	<p>Unclassified Report</p> <p>A brief review of powder technology is presented, covering aspects of interest to the SAPAG project. Included in this portion is a discussion of the methods of producing finely divided powders and the possible mechanisms involved in agglomeration. The techniques used in the production of fine powders for use in the SAPAG experiment are described and representative micrographs of powder preparations, as well as number density distributions, are presented and discussed.</p>	<p>UNCLASSIFIED</p> <ol style="list-style-type: none"> <li>1. Submicron particle production</li> <li>2. Agglomeration</li> <li>3. Particle size distribution</li> </ol> <ol style="list-style-type: none"> <li>I. Tannenbaum, I. R.</li> <li>II. Heliodyne Corporation Research</li> <li>III. Note 19</li> <li>IV. Contract No. DA 04-495-AMC-458(Z)</li> </ol>
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A brief review of powder technology is presented, covering aspects of interest to the SAPAG project. Included in this portion is a discussion of the methods of producing finely divided powders and the possible mechanisms involved in agglomeration. The techniques used in the production of fine powders for use in the SAPAG experiment are described and representative micrographs of powder preparations, as well as number density distributions, are presented and discussed.

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1. Submicron particle production
  2. Agglomeration
  3. Particle size distribution
- I. Title  
II. Tannenbaum, I. R.  
III. Heliodyne Corporation Research  
Note 19  
IV. Contract No. DA 04-495-AMC-  
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<p>Heliodyne Corporation, Los Angeles, California 90064  <b>TECHNIQUES FOR PRODUCING SUBMICRON-SIZE PLASTIC PARTICLES</b>, by L. R. Tannenbaum. June 1955. 27 p. Incl. illus. (ARPA Order No. 340; Project DEFENDER) (Heliodyne Corporation Research Note 19) (Contract No. DA 04-495-AMC-458(Z))</p> <p>Unclassified Report</p> <p>A brief review of powder technology is presented, covering aspects of interest to the SAPAG project. Included in this portion is a discussion of the methods of producing finely divided powders and the possible mechanisms involved in agglomeration. The techniques used in the production of fine powders for use in the SAPAG experiment are described and representative micrographs of powder preparations, as well as number density distributions, are presented and discussed.</p>	<p>UNCLASSIFIED</p> <p>1. Submicron particle production  2. Agglomeration  3. Particle size distribution  4. Title  I. Tannenbaum, L. R.  II. Heliodyne Corporation Research Note 19  III. Contract No. DA 04-495-AMC-458(Z)</p> <p style="text-align: center;"></p> <p>UNCLASSIFIED UNCLASSIFIED</p>	<p>Heliodyne Corporation, Los Angeles, California 90064  <b>TECHNIQUES FOR PRODUCING SUBMICRON-SIZE PLASTIC PARTICLES</b>, by L. R. Tannenbaum. June 1955. 27 p. Incl. illus. (ARPA Order No. 360; Project DEFENDER) (Heliodyne Corporation Research Note 19) (Contract No. DA 04-495-AMC-458(Z))</p> <p>Unclassified Report</p> <p>A brief review of powder technology is presented, covering aspects of interest to the SAPAG project. Included in this portion is a discussion of the methods of producing finely divided powder and the possible mechanisms involved in agglomeration. The techniques used in the production of fine powders for use in the SAPAG experiment are described and representative micrographs of powder preparations, as well as number density distributions, are presented and discussed.</p>	<p>UNCLASSIFIED</p> <p>1. Submicron particle production  2. Agglomeration  3. Particle size distribution  4. Title  I. Tannenbaum, L. R.  II. Heliodyne Corporation Research Note 19  III. Contract No. DA 04-495-AMC-458(Z)</p> <p style="text-align: center;"></p> <p>UNCLASSIFIED UNCLASSIFIED</p>
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