Using benzene as dispersing medium, a test tube containing the correct volume of a dispersion of the dust in liquid was shaken vigorously, then this was poured into the cell immediately and covered instantly. After standing about 5 minutes the air flow was started. If the proper flow rate had not been determined previously, the particles were closely watched while the flow was increased gradually. When any motion appeared the flow was decreased. The course of the drying can be watched through the glass top. Large particles do not move readily, but great care must be taken with the finer particles.

With this instrument, nearly all of the dispersions made were satisfactory, whereas by former procedures, a good dispersion had to be chosed from many trials. Equally good results could be obtained by merely leaving the dish stand on a bench with the cover slightly raised, though more time was required for drying. If dispersion is not good immediately on pouring the benzene-dust mixture into the dish, the procedure must be repeated as it is impossible to improve the dispersion thereafter.

Particle-Size Measurement

The dish containing a representative sample of the particles, completely separated and uniformly distributed as described above, was placed under the microscope, a rectangular grid in the eyepiece was superimposed on it, and the sizes of all particles within a specified area were measured. This was done by estimating the size of each particle compared with the distance between the finer lines of the grid or, more accurately, by means of a filar micrometer.

As dust particles are usually irregular, any one of several dimensions of the particle may be measured. Some authorities use the linear average diameter, while others define average diameter as that figure that represents the true volume, surface area, or some other value of interest. Some use the length or width of the smallest circumscribing rectangle or the diameter of the circle having the same area as the projected image of the particle. Hawksley[70] describes many of these methods of size measurement. It appears to be most common to measure the distance between the two points on the particles that are farthest apart in a given horizontal direction chosen for all measurements. This, obviously, may be any value from the minimum to the maximum visible dimension of the particle, depending on how the particle is oriented with respect to the grid, but when used on a large number of particles the statistically mean visible dimension is obtained. It must be remembered, however, that there is a vertical dimension that is not considered by this method. Experiments have shown this to be the smallest dimension, at least for the larger size ranges in which such a test could be made, so that the minimum visible dimension might be a better criterion of particle size.

To test the preceding theory, a sample of coarse coal dust was selected and particle size analyses were made by both methods. A screen analysis was calculated from each result and compared with the true screen analysis as determined by experiment. The results, given in table 5, show that, for the total of all particle sizes below 200-mesh, the minimum visible dimension method gives better agreement with screen analyses that the conventional procedure. Unfortunately, since particles less than 200-mesh size are not amenable to conventional screen analysis, no proof is furnished that the minimum visible dimension method is more reliable for finer particles as well. It should be noted that, regardless which method is used, a shape factor can be applied in an attempt to obtain more correct volumes. A similar comparison of liquid sedimentation methods with screening is given by Webb.[71]

70/ See footnote 65.
71/ See footnote 67.

TABLE 5. - Comparison of different methods for particle-size measurement

Size range	Percent by weight		
	(1)	(2)	(3)
Below 10 microns	0.90	0.64	
Below 20 microns	4.74	9.09	
Below 44 microns (325-mesh)	20.99	41.90	
Below 74 microns (200-mesh)	52.31	88.94	91.1

1/ By lateral direction measurement.
2/ By minimum visible dimension method.
3/ By screen analysis.

It is important that the field selected for particle-size measurement contain enough larger particles to constitute a representative sample. Such a field, however, may contain so many smaller particles that their measurement becomes tedious if a large range of particle sizes is to be determined. In such cases, it was found convenient and accurate to use a small part of the field and sometimes a higher power objective lens, especially when measuring the smaller particles. An overlap of sizes is desirable as a check on accuracy.

Fine particles, although constituting a small percentage of the dust leaving the gasifier, must be determined accurately since they are difficult to remove and constitute the bulk of the particles remaining after preliminary purification. Although it was essential to obtain complete dispersion for these tests, it should be pointed out that for certain purposes, for example, studying the operation of industrial dust-removing equipment, it is more important to determine the size of agglomerates existing in the gas stream, which may be quite different from the ultimate particle size obtained by the method discussed.

Certain optical methods applied directly to the gas stream may be helpful in particle size measurements, although difficulties of interpretation occur, aggravated by the complexity of the theory of light scattering. These problems are discussed in detail by Hawksley.72/ A sedimentation method was found suitable for certain purposes. A small gas stream sampled at isokinetic velocity was passed for a few seconds through a horizontal glass tube about 2 inches in diameter with a microscope slide attached to the top inside. Immediately after the flow was stopped the tube was turned over and allowed to stand until all particles had settled. The slide was then removed from the glass tube, and the deposit on it was examined in a microscope with light from above to determine the amount of agglomeration in the original gas stream. This method assumes that no agglomeration occurs during settling.

From the results of the particle-size determination, it is customary to calculate an average particle diameter. As stated previously, this average is often defined as the diameter that represents the total number of particles in some way, for example, diameter of a particle having the average surface area, volume, etc., therefore, it is not always the average linear diameter.

It is obvious that two dusts with the same average diameter may be very different if one has a much greater variation in particle size than the other. Thus, some sort of

72/ Hawksley, P.G.W., The Physics of Particle Size Measurement: Pt. I, Optical Methods: British Coal Utilization Research Assoc. Monthly Bull., vol. 16, No. 4, April 1952, p. 117.

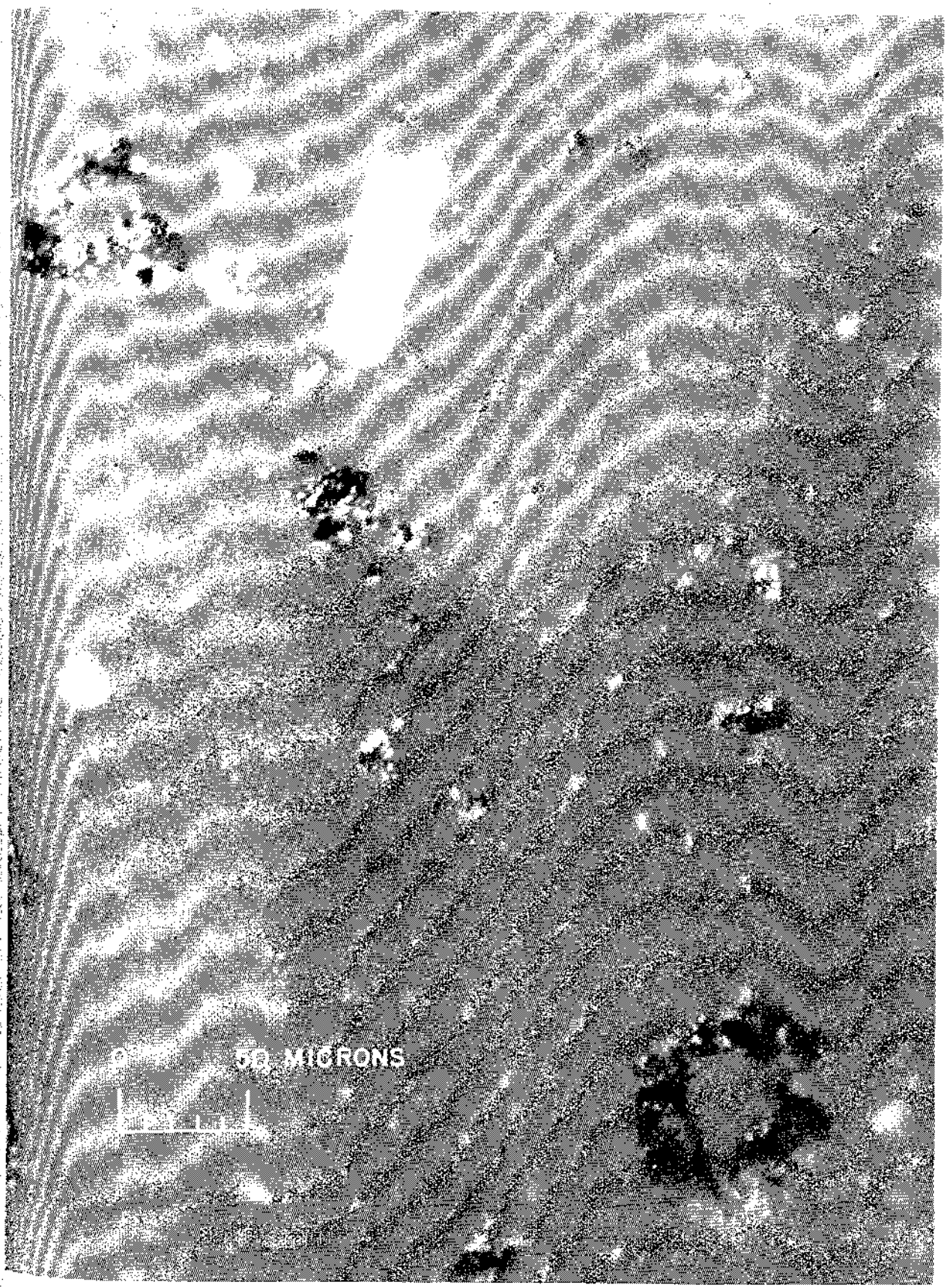

Figure 18. - Residue from gas leaving atmospheric gasifier (No. 4).

Figure 19. - Typical slag particles.

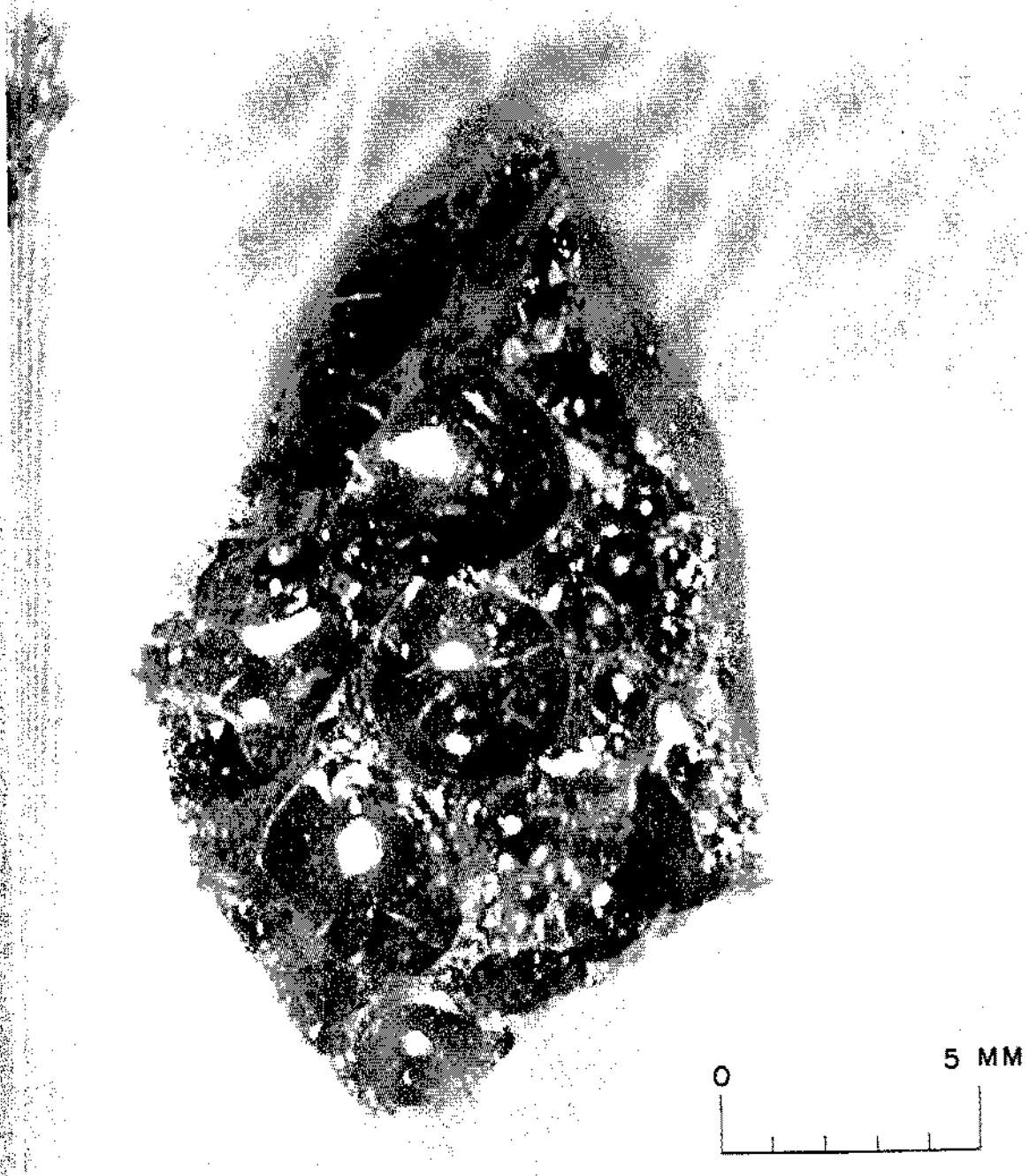

Figure 20. - Interior of slag particle.

mathematical or graphical representation of particle size distribution is often necessary. This problem has been discussed by Drinker,[73] and the American Society for Testing Materials has established standards.[74]

Microscopic Examination

In addition to particle-size determination, microscopic examination of the solids removed from the gas stream may yield important information on the exact conditions to which they are subjected in the gasifier. Such information is difficult to obtain in other ways and may constitute an important contribution to the problem of gas production. The usual type of microscope lighting from below as found to be almost useless for this purpose. Often it was unsatisfactory even for particle-size determination because of the difficulty in distinguishing between a large particle and a cluster of small particles. Vertical illuminators such as are used in metallurgical microscopes proved much better, but best results were obtained by using unbalanced lighting from different sides and angles such as is common practice in photographic work. At higher powers the "Leitz Microlux" or "Ultrapak" lighting system must be used to get this effect. The true appearance of the particles could be determined more readily and surface detail was much clearer when viewing dry dispersions rather than wet or submerged particles. The previously described method for obtaining dry dispersions was very helpful.

A smooth, colored background of medium reflectivity was found best for these particles. Gray was preferable when black and white photographs were to be made. Occasionally, the substage mirror was used to make a background, but its brightness was kept below that of the white-ash particles and above that of the black-residue particles, so that both could be readily distinguished from the background. Figures 18, 19, and 20 are examples of this technique. In figure 18, the white unfused ash is readily distinguished from the black carbonaceous particles of residue, and surface texture is readily discernible even at fairly high powers. It may be readily seen that such examination might yield much information on conditions of temperature, etc., prevailing in the gasifier. The ring formations are often seen in these residues. Figures 19 and 20 show typical slag (fused-ash) particles.

The apparent vertical dimension is greatly exaggerated under the microscope. The top and bottom of the particle seldom can be brought into focus at the same time, so that considerable interpretation is necessary to determine the true appearance of the particle by direct examination, especially when using higher powers. Long-focus objective lenses of low numerican aperture reduce these difficulties and should be used whenever possible, in spite of their low resolving power. It is better to increase the power of magnification by changing oculars. Manipulation of the particles under the microscope was found to be extremely advantageous for determining their characteristics.

It is difficult to determine the characteristics of submicroscopic particles, but the electron microscope is helpful, especially if replica or shadow techniques are used.

Petrographic Methods

Further information on conditions existing in the gasifier can be obtained by petrographic and paleobotanical techniques. These methods allow the determination of mineral constituents, from which facts on the true gasification temperature and mechanism of solid particle breakdown can be deduced. Petrographic techniques for identification of atmospheric dust particles[75] have been published in recent years.

73/ See work cited in footnote 57, p. 144.

74/ American Society for Testing Materials, 1942, Book of ASTM Standards: Pt. 2, 1942, p. 1414; Pt. 3, 1942, p. 1561.

75/ Foster, W. D., and Schrenk, H. H., Petrographic Identification of Dust Particles: Bureau of Mines Rept. of Investigations 3368, 1938, 10 pp.