Discussion

We have determined drop velocities and the spatial size distribution from different series of photographs because the double exposure necessary for velocity measurement tends to obscure the smaller drops. This effect is less objectionable in velocity measurements, since a fraction of the small drops will suffice to determine the average velocity of such drops. For a spray which diffuses little light and consequently gives very sharp drop shadows, or if only larger drops (over 50 microns) are of interest, it might be feasible to use double exposures for both distribution and velocity measurements.

The number of photographs which must be taken and drops which must be counted rise sharply as the desired accuracy increases. The problem is a statistical one.

Even though a large part of the work of an analysis can be made routine, and does not require highly trained personnel, it is still quite laborious to apply the technique described in this paper to a large number of points throughout a spray. In many applications it may not be worth while to obtain the detailed quantitative analysis of which the method is capable. Often the effort can be better spent getting semiquantitative information at a few points of a spray which would be sufficient to indicate the trends and general nature of the spray. Adaptations of this method also might be used to examine the mechanism of formation of a spray or its behavior as it impinged on an object or at some other point of special interest.

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Discussion

J. P. Longwell.[9] When one wishes to study the evaporation or combustion of a cloud of liquid drops, it is immediately apparent that lack of information on the size distribution of drops and their relative velocity to the air stream prevents detailed consideration of these processes. This is generally recognized and this lack of information does not result from lack of interest in the subject but is due to lack of suitable experimental technique for making the necessary measurements. It is, therefore, of interest to hear of the development of another technique for making such measurements.

This new technique must compete with other available methods such as those which collect drops on a slide for later counting and measuring. As pointed out by the authors, there is a tendency to collect a larger proportion of big drops rather than of small drops on an obstacle placed in an air stream. By use of reference (3) of this paper, it is possible to calculate the magnitude of such errors.

Table 1 of this discussion gives the error in size distribution due to this selective sampling for the case of a spray from an air-atomizing nozzle giving a mass median drop diameter of 20 microns. The air velocity was 70 fps and the collecting plate width was 0.3 in.

It is seen that the mass median partial diameter would be about 10 per cent too large and the error for smaller drops would be somewhat greater. More accurate results would be obtained for the coarser sprays generally encountered and, by knowing collection efficiencies, it is possible to correct these results and

TABLE 1 EFFECT OF SAMPLING ERROR ON SIZE DISTRIBUTION

Fraction of total mass above a given diameter	Diameter for original spray, microns	Diameter for sample, microns	Error per cent
0.9	11.5	13.1	14
0.75	15.3	17.3	13
0.5	20	22.1	10
0.25	26.7	28.5	7
0.1	32.0	32.7	2

therefore improve the accuracy. It is felt that this accuracy is adequate for many purposes; so comparison of this technique with the photographic technique would be on the basis of the time consumed in procuring data. In measuring a sample on a slide, one would generally photograph it for future counting. In this case the photographic technique is not critical, since all drops can be in the focal plane. Measuring the drops on the negative is also easier, since it is not necessary to use judgment as to when a spot is in or out of focus and machines have been developed to count and measure drops on such a negative.

The photographic technique described in this paper can give information on drop velocity which the other techniques do not give; however, it is not certain that this technique is necessarily more accurate or less time-consuming than other available techniques.

J. M. Pilcher.[10] The authors have made a valuable and noteworthy contribution to the complex problem of characterizing a spray in terms of drop-size distribution. The greatest difficulty involved in this problem is accurate sampling of the spray to eliminate discrimination against either the larger or smaller drops; and, in this regard, they have made a wise choice in selecting the photographic method which obviates the placement of collecting objects such as slides in the spray.

The principal shortcoming of this method appears to be the complex counting operations and the measure of drop sizes which require much time and tedious effort. This objection might be overcome, however, by the use of a semiautomatic device for counting and sizing the drops such as the "differentiating droplet counter" developed at Douglas Aircraft Company by J. H. Rupe, or the scanning device developed at the University of Wisconsin by W. R. Marshall and his associates. These instruments are capable of scanning at rates of about a thousand drops per minute, and the human element is eliminated from the counting process; however, a sharp negative with high contrast between drops and background is required.

It appears that the method described in the paper may be most suitable as a primary means of calibrating some less tedious and time-consuming indirect method. Such a method might be based upon the absorption or diffraction of light, or upon the electrical charges carried by the droplets.

Authors' Closure

As both Mr. Longwell and Mr. Pilcher point out, the method described in this paper is laborious and time consuming. We agree that for many problems of spray analysis, faster methods are more suitable.

We have considered the use of mechanical counting devices like those mentioned by Mr. Pilcher, but we have not been able to work out a satisfactory way to use any of them on our negatives.

Mr. Longwell suggests the use of Langmuir and Blodgett's work (footnote 3) to compute correction factors to compensate for discrimination against small drops in samples collected on slides. Under some circumstances this may be feasible, but this procedure must be used with great caution. For their calculations, Langmuir and Blodgett assume that the air mass is free of turbulence

[9] Esso Laboratories, Standard Oil Development Company, Linden, N. J.

[10] Battelle Memorial Institute, Columbus, Ohio. Mem. ASME.

and that at a distance from the obstacle the air is moving at uniform velocity and the drops are at rest with respect to the air. These conditions are not even remotely approached in many sprays. Fig. 7 shows that for the spray described there the average velocities of drops varied through a tenfold range. The velocities of individual drops had an even wider variation. Under such conditions, calculations from footnote 3 might indicate where discrimination begins to be an important factor in collection on slides, but it cannot be relied on for numerical corrections.