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SOME NOTES ON A LIGHT SCATTERING TECHNIQUE FOR MEASURING THE MEAN DROPLET SIZE OF SPRAYS

by

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Introduction

There is often great difficulty in measuring mean droplet size and drop size distribution in sprays because of sampling problems. This is particularly true if the spray is produced in the practical environment, for example in a high pressure combustion chamber, and the spray density is high. In recent years there has been a greater need to evaluate the characteristics of atomisers under such conditions and hence greater interest shown in optical methods which present the most convenient means for examining spray characteristics.

It is not intended in this brief note to discuss in detail the principles involved with diffractive scattering methods of measuring mean droplet size, - this has been done very effectively elsewhere - but merely to outline some of the practicalities of producing a reliable instrument based on one method which has considerable promise. One of the early papers describibg and evaluating this method was published by Dobbins, Crocco and Glassman in 1963, but the theoretical background on which the method is based was available much earlier.

Light scattering technique

The optical method due to Dobbins, Crocco and Glassman(1) is based on the forward scattering of a parallel beam of monochromatic light passing through a spray. The type of apparatus used by Dobbins et al to study this method is illustrated in Fig. 1. It was found that for sprays described by the Upper Limit Distribution Function, defined originally by Mugele and Evans(2), having parameters of spread and skewness within specified limits, the light intensity profile was unique - Fig. 2. Roberts and Webb(3) extended the results to a greater range of spread and skewness in the U.L.D.F. without significant change in the mean theoretical profile and found that the least standard deviation between experiment and theory occurred at approximately one-tenth normalised intensity in the profile. The measurement of the position in the profile at which this intensity is found will enable the mean droplet size of the spray to be calculated with minimum error.

Description of Instrument

The design and development of the first optical bench used at Cranfield for determining mean droplet size by the above method is fully described in reference (4). Improvements and final optimisation of the instrument are detailed in reference (5) and reference (6) respectively. A brief description of the instrument in current use is as follows.

A beam of light provided by a high pressure Mercury vapour lamp, HBO/107/1, manufactured by Osram, is regulated in size by an aperture control before passing through a green interference filter and focussed on to a 0·020 ins diameter collimating aperture. (See fig. 3). The filter transmits approximately 45% of the incident light in the wave band 5440 ± 120 Angstrom units. The collimating aperture size controls the sharpness of the beam edge cut-off.

The subsequent monochromatic beam is brought to a high degree of parallelism by a 36 ins focal length collimating lens. The beam normally controlled at approximately 0·25 ins diameter is reflected through the spray under investigation to a receiver lens by an optical quality plane silvered mirror mounted on light springs and at 45° to the original axis of the beam, hence forming an "L" shaped optical peth. The receiver lens, identical to the collimating lens, is focussed on to a 65 micron diameter aperture in an otherwise light tight photomultiplier box.

The photomultiplier box, mounted on a trolley, can be traversed across the focussed beam with the aid of a fine screw jack and dial test indicator. The signal from an inductive displacement transducer mounted on the trolley gives a very sensitive indication of traverse position and is displayed on the X axis of an X - Y plotter while the signal from the photomultiplier is normally applied to the Y axis.

Discussion

The result of a typical photomultiplier traverse is shown in Fig. 4.

One considerable problem in measuring the illumination profile is the obvious need to curtail the central spike of unscattered light. This spike can be so large that it can make the assessment of centre line intensity almost impossible. If, however, one limits the size of the collimating aperture the magnitude and extent of unscattered light can be controlled. Another reason for limiting the size of the collimating aperture is parallelism of the beam. Dobbins suggested a focal length/collimating aperture ratio of 1250. With a 36 inch focal length collimating lens, satisfactory results were obtained with a 0·020 ins collimating aperture. Another difficulty in measuring the illumination profile occurs when spray densities are very high. Under these conditions the intensity of scattered light at considerable distances from the beam control line become so low that it becomes

$\frac{f_c}{d_c} = 1800$

$\frac{36 \times 1000}{20} = 1800$

difficult to produce consistent profiles. Variation of beam size by aperture control and changes in collimating aperture size are necessary in order to overcome this problem. Adjustments of this kind have produced marginal differences in droplet size determination, differences usually being less than 3·5% which appears to be in agreement with similar test by Yaslonim[7].

Comparisons of mean droplet size measured with the optical apparatus and those determined from magnesium-oxide slides are normally within 7% for sprays finer than 100 microns. Recent comparisons with a liquid nitrogen technique at more realistic spray densities have shown better agreement and this method is providing a means of calibrating the optical bench. The liquid nitrogen technique illustrated in figure 5 is similar to that discussed by Street and Danaford[8] . However, only micro photographs of samples of the frozen droplets are taken and no sieving is carried out. A typical miro photograph of frozen droplets is shown in fig. 6.

To date the instrument described above has been successfully used in studying the characteristics of practical airblast atomisers operating under ambient pressures from atmospheric to 250 p.s.i. absolute, air/fuel ratios from 0·5 to 13 and a wide range of air velocities.

References

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4. "An Optical Instrument for the Measurement of Mean Droplet Size of Sprays"

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7. "Determination of the Size of Particles by Light Scattering"
   Yaslonim, I.
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8. "A Technique for Determining Droplet Size Distribution using Liquid Nitrogen"
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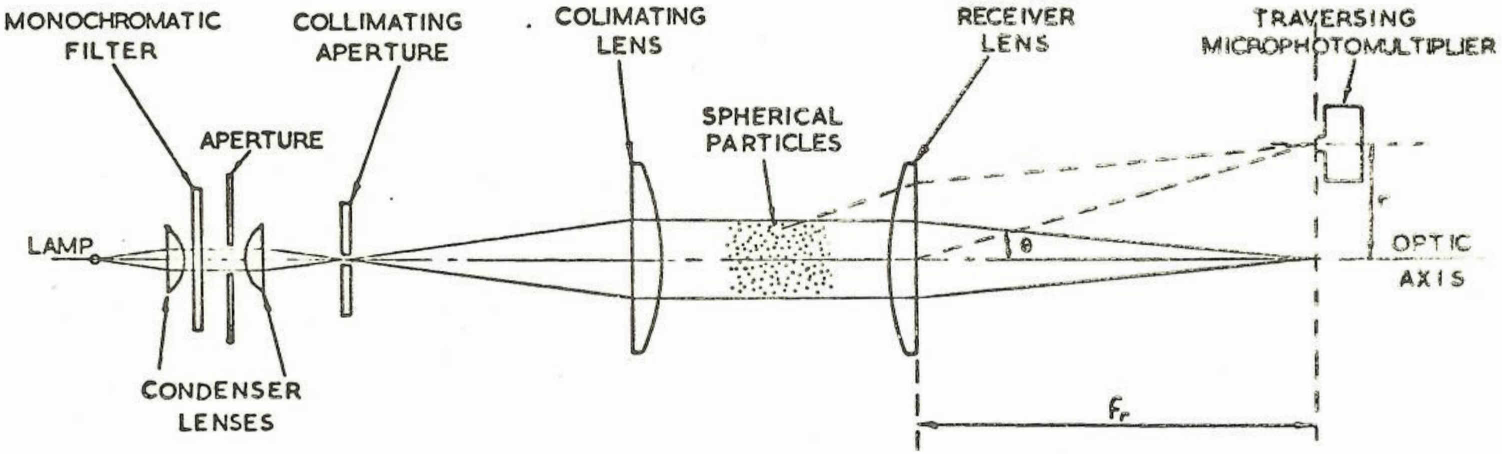


DOBBINS OPTICAL APPARATUS

FIG. 1

MEAN THEORETICAL ILLUMINATION PROFILE

DOBBINS, CROCCO AND GLASSMAN

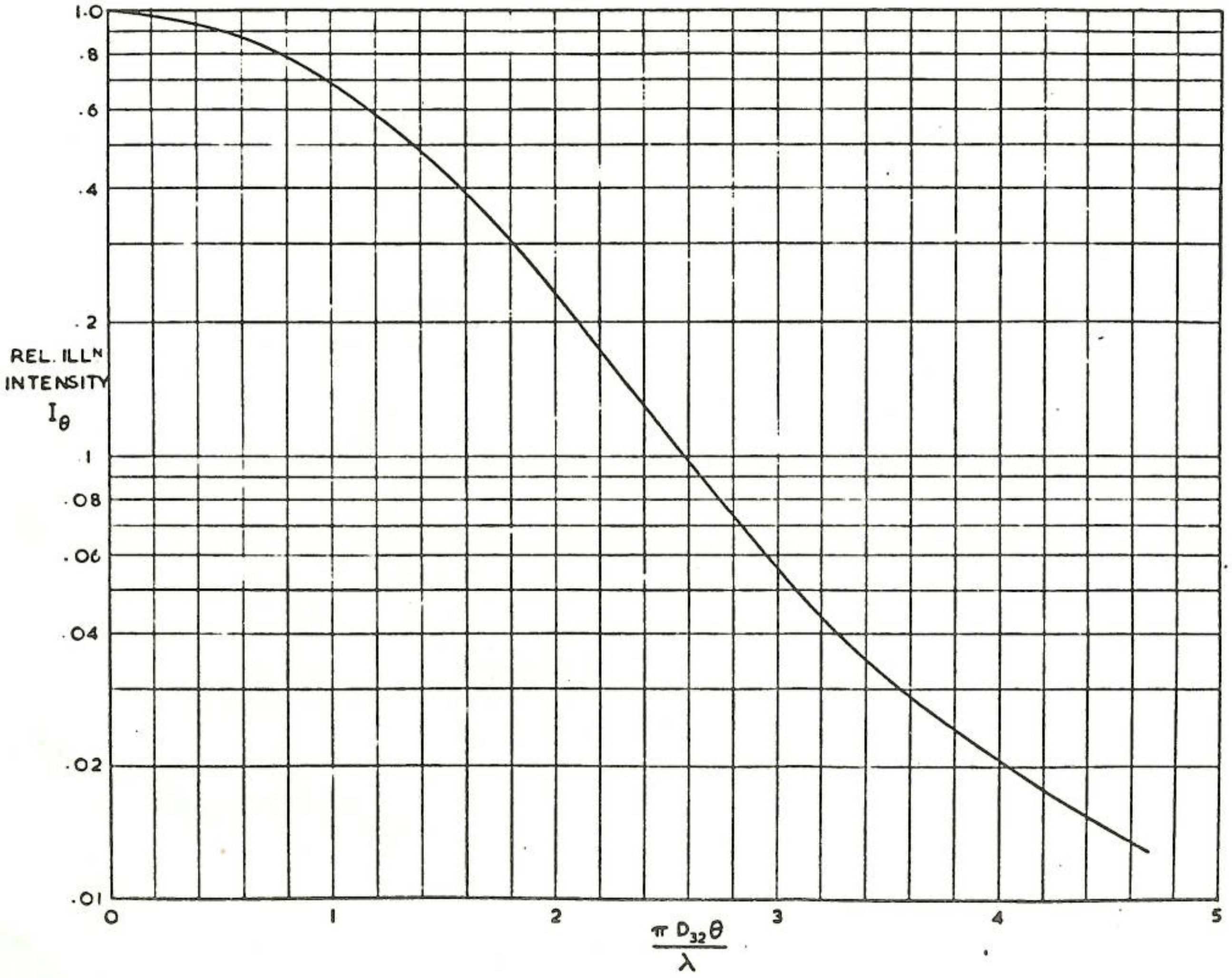
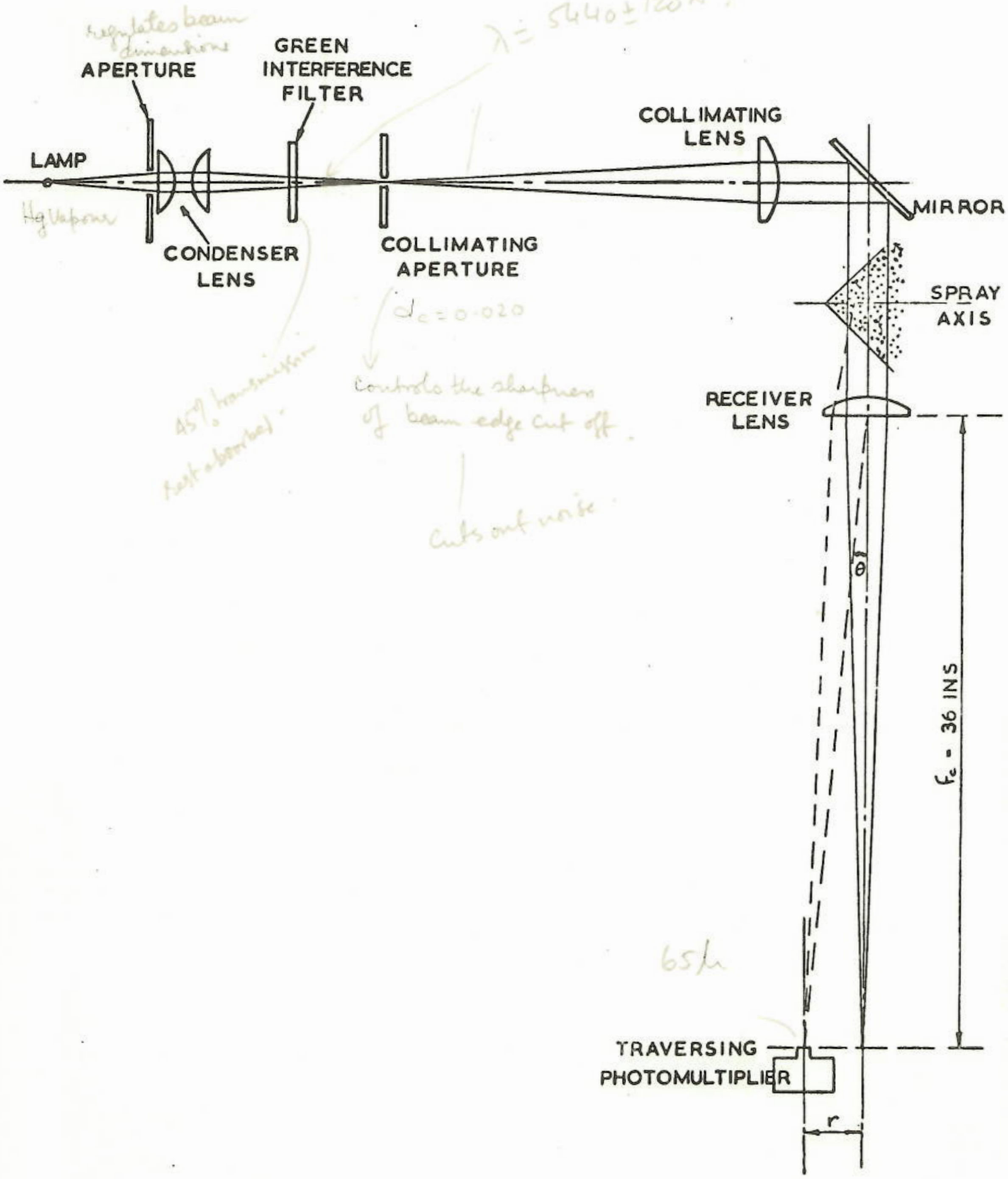


FIG. 2

FIG. 3

OPTICAL MEASURING APPARATUS



regulates beam dimensions

Hg Vapour

$\lambda = 5440 \pm 120\,\mathring{A}$.

45% transmission rest absorbed.

$d_c = 0.020$

controls the sharpness of beam edge cut off.

cuts out noise.

65μ

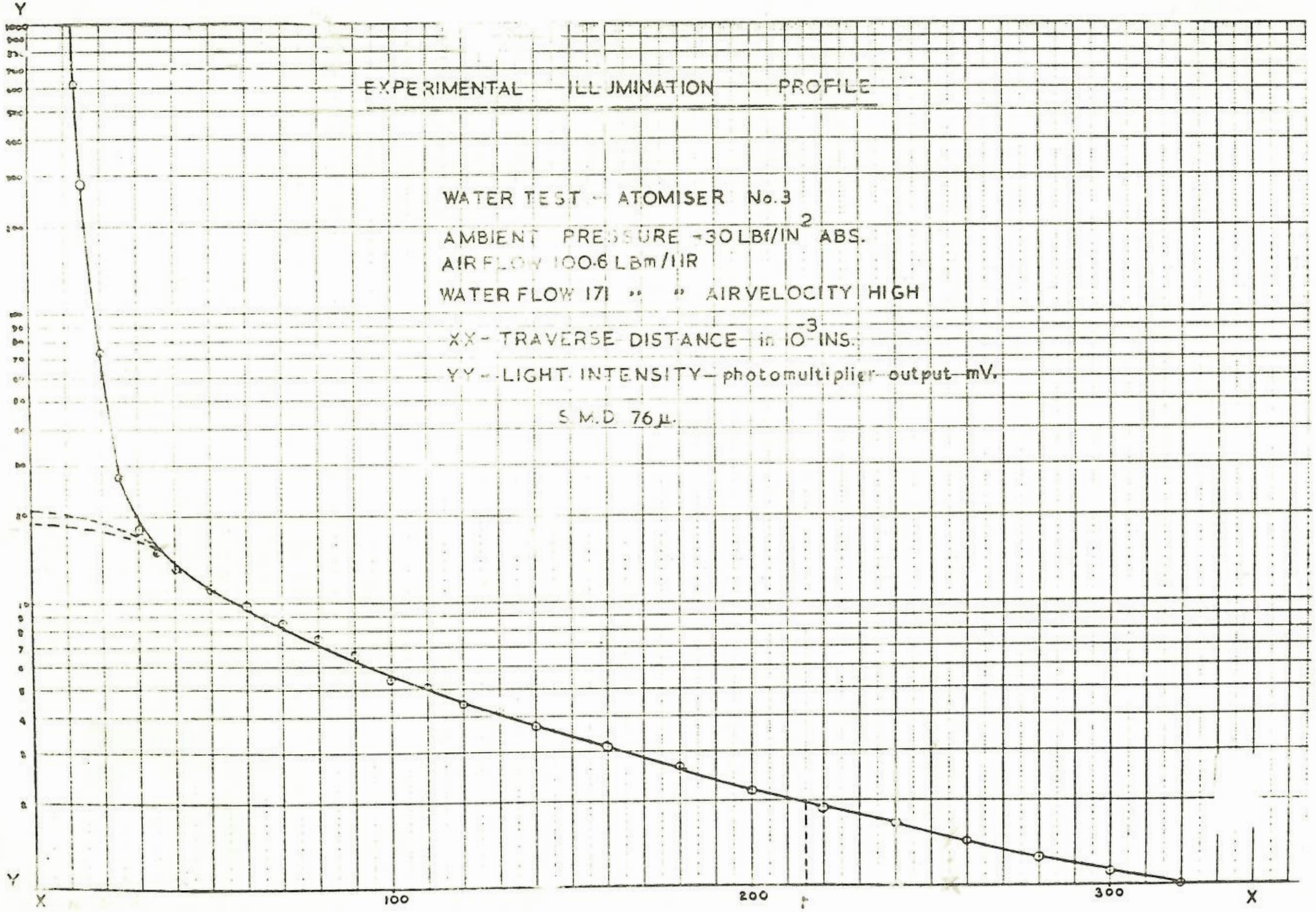
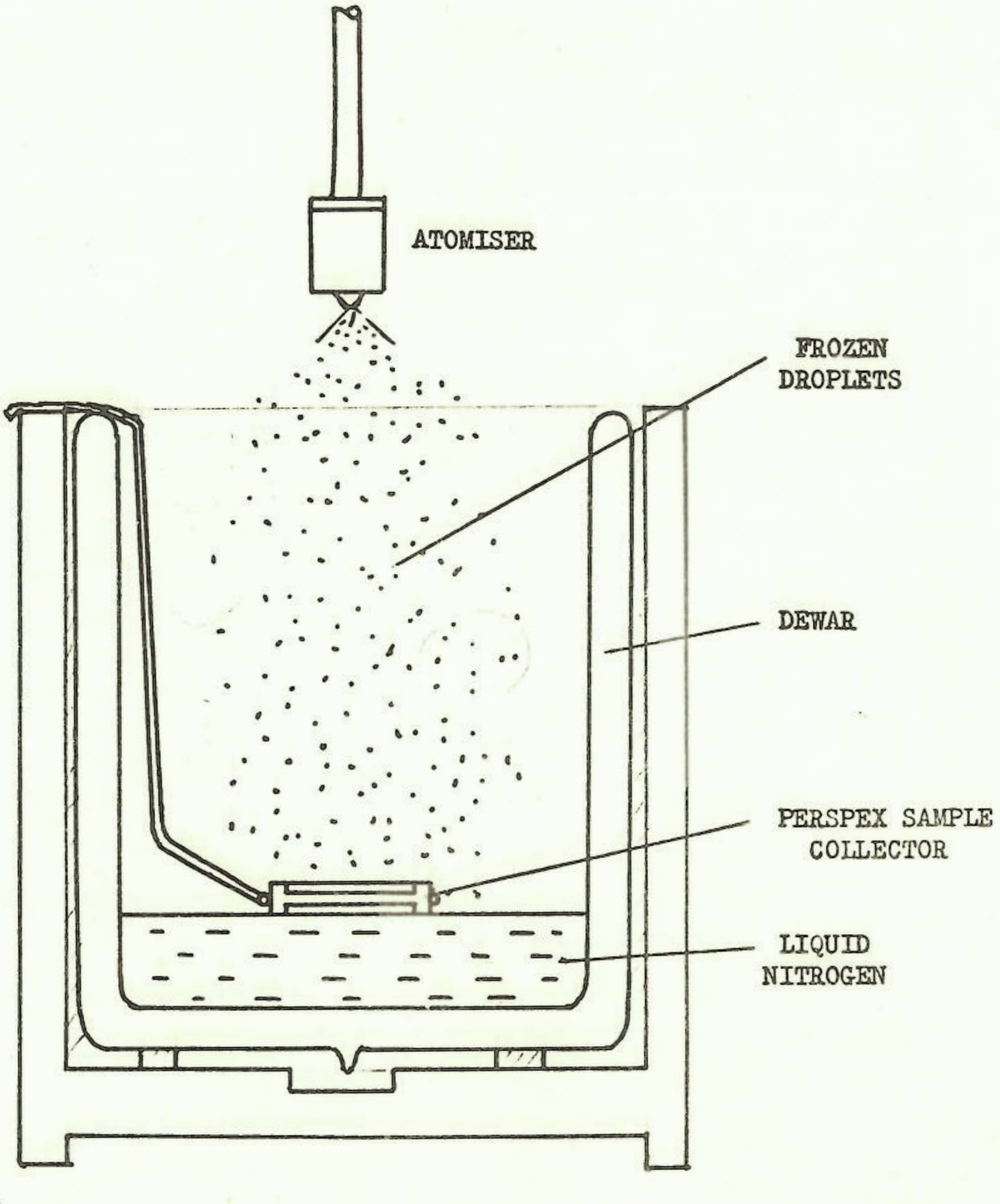

Y
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
Y
EXPERIMENTAL ILLUMINATION PROFILE
WATER TEST – ATOMISER No.3
AMBIENT PRESSURE – 30 LBf/IN² ABS.
AIRFLOW 100·6 LBm/HR
WATER FLOW 171 " " AIRVELOCITY HIGH
XX – TRAVERSE DISTANCE in 10⁻³ INS.
YY – LIGHT INTENSITY – photomultiplier output – mV.
S.M.D 76 µ.
X
100
200
300
X

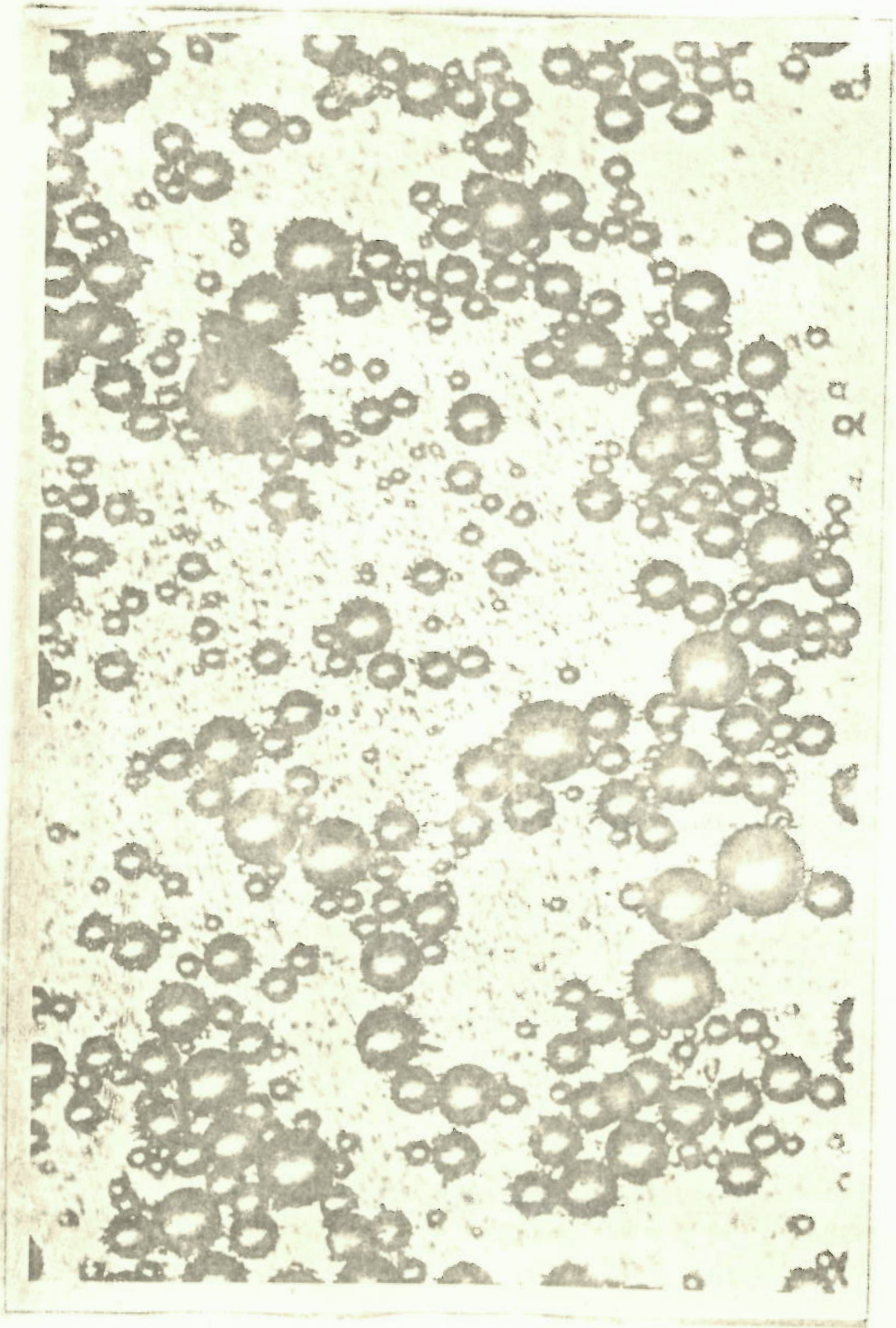
FIG. 4

FIG. 5



APPARATUS FOR CALIBRATING ATOMISER

FIG.6



MICRO-PHOTOGRAPH OF FROZEN DROPLETS

(100:1 MAG.)