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ILLINOIS STATE WATER SURVEY
and the
UNIVERSITY OF ILLINOIS
Urbana, Illinois

STUDY AS TO MERITS OF VARIOUS RAPID RAINDROP COUNTING AND SORTING TECHNIQUES

Final Report
15 May 1956 — 31 March 1958
Contract No. AF 19(604)-1900

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Geophysics Research Directorate
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ILLINOIS STATE WATER SURVEY
METEOROLOGIC LABORATORY
at the
UNIVERSITY OP ILLINOIS
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PINAL REPORT

Contract No. AP19(604) - 1900

15 May 1956 - 31 March 1958

Prepared by

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Project Director

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Illinois State Water Survey

The research reported in this document has been sppnsored by the Geophysical Research Directorate of the Air Force Cambridge Research Center, Air Research and Development Command.

TABLE OF CONTENTS

ABSTRACT

An extensive literature search has been made to evaluate known instruments, designs, and methods of counting rain and drizzle drops according to their sizes. Emphasis has been placed on the techniques that are adaptable to automatic registration of drop count versus various powers of drop diameter.

The comprehensive literature search has resulted in an annotated bibliography of raindrop sizing and counting techniques. The optical mechanical spectrograph, being developed at the University of Michigan, was supported by funds under this contract as it appeared to be a highly promising device. Further work was recommended, in view of the fact that the technique has considerable merit.

Near the termination of this contract, a technique of measuring the forward scattered light was called to the contractor's attention. Preliminary study indicates that an instrument should be constructed and tested.

The automatic scanning of photographic films, which have been exposed using forward lighting of the drops to eliminate the "hot" spot, or scanning of photographs of streaks made by drops falling past an open shutter, warrants further study.

LIST OF PUBLICATIONS

1. "An Evaluation of Raindrop Sizing and Counting Techniques," by John E. Pearson and Gordon E. Martin, Scientific Report No. 1, AFCRC-TN-57-628, ASTIA 146773, Nov. 1957.
2. "Illumination of Highly Reflective and Transparent Spheres as an Aid to Automatized Counting," by R. C. Krump (Appendix A).
3. "Evaluation of a Photoelectric Raindrop-Size Spectrometer," by A. N. Dingle, prepared as a final report under subcontract No. 1 with the University of Michigan, August 1957.

PERSONNEL

This report was written under the general direction of William C. Ackermann, Chief of the Illinois State Water Survey. The principal investigator was J. E. Pearson, Professor of General Engineering at the University of Illinois, who devoted approximately one-third time to this study. He was ably assisted by G. E. Martin, Instructor of General Engineering at the University of Illinois, on a similar time basis. Principal consultants on the Illinois State Water Survey staff were E. A. Mueller and D. M. A. Jones while G. E. Stout served as Project Director. Research assistants were R. C. Krump who performed experimental work on forward lighting of drops (Appendix A) and H. S. Tung who evaluated the feasibility of concentrating raindrops into a funnel for more rapid counting and of using a parallel plate electrical condenser as a pick-up device.

TRIPS

For the purpose of collecting background material from many unpublished sources and reviewing the work of other researchers on drop size measuring, visits were made to the following places:

A. Weather Radar Unit, Geophysics Research Directorate, Air Force Cambridge Research Center, Milton, Massachusetts.

B. University of Wisconsin, Madison, Wisconsin.

C. University of Michigan, Ann Arbor, Michigan.

D. Armour Research Foundation, Chicago, Illinois.

E. Modine Company, Racine, Wisconsin.

F. Argonne National Laboratory, Chicago, Illinois.

G. Woods Hole Oceanographic Institute, Woods Hole, Massachusetts.

H. Times-Facsimile Corporation, New York, New York.

I. Eastman-Kodak Company, Rochester, New York.

Credit is due numerous individuals at the above organizations for information and consultation received.

STATEMENT OF WORK

The contract states that, "the contractor shall conduct studies and experimental investigations directed toward the evaluation of available instruments, designs, and methods applicable to the counting of rain and drizzle drops according to their sizes. The investigators will determine what technique or combinations thereof are suitable for the automatic counting and recording of representative samples of all drop sizes equal to or above 0.1-mm in diameter, which are present in liquid precipitation. Counts should be at a rate approximating 5 samples per minute.

"Consideration will be given to the count rate requirements of instruments which will yield the required samples, and therefore to the properties of a raindrop sample which is suitably representative. Possible techniques for automatic registration of drop count vs. various powers of the drop diameter and automatic histogram presentation will be investigated.

"The work will also include a study of the utility of the raindrop camera developed by the Illinois State Water Survey. Consideration will be given to use of the Spray Counter developed by the University of Wisconsin as the counting and recording system to be used in conjunction with this camera or other detection unit. The advisability of copying the optical mechanical spectrograph of Ohio State University, thought to give suitable counts of the smaller drops, will be studied also. A limited purpose instrument such as this last named must, of course, be used in conjunction with others in a complete system. In addition to the above named, the investigators will study all other hopeful techniques. Occasional travel by the investigators will be undertaken for purposes of studying the operation of already manufactured devices which show promise of application to this raindrop problem, and for conferring with other interested parties on problems of mutual concern."

INTRODUCTION

Data on raindrop size-distribution are very limited, principally due to lack of a technique for the collection of an adequate sample and to the need for reducing enormous quantities of data. Because as many as two thousand drops may occur in a cubic meter sample, the task of manually measuring and counting many sizes of samples is quite great. At the same time the need for drop data is increasing. Drop size-distributions seem to vary from one climatic region to another and under various weather conditions. This investigation was undertaken at the request of the sponsoring agency to evaluate the raindrop sizing and counting instruments and techniques for automatic registration of drop count versus various powers of drop diameter.

This report summarizes the study conducted under this contract. Specific details as to the various types of raindrop sizing and counting techniques may be found in Scientific Report No. 1 under this contract. In addition to an extensive literature search and correspondence with various British manufacturers of automatic counting and sorting devices, several investigations were conducted to evaluate several new theories. In order to aid in the development of the optical mechanical spectrograph at the University of Michigan, a subcontract was established to support its evaluation.

INVESTIGATIONS

Literature Search

To evaluate the available instruments, designs, and methods applicable to the counting of rain and drizzle drops according to their sizes, a comprehensive literature search was undertaken. The various devices and techniques used to sense the size distribution of raindrops were classified according to the following methods:

(a) sizing by images on a surface - slate, filter paper, greased wire or thread, nylon screen, slides, and oil

(b) mechanical sorting - dough pellets, ice pellets

(c) inertia sorting - wind tunnel, multicylinder

(d) velocity sorting - revolving discs

(e) energy sorting - microphone, impact on pen arm, impact on aluminum foil

(f) radioactive sorting - attenuation from radioactive elements

(g) sorting by change in electrical characteristics- corona discharge and magnetic induction, corona discharge and collector plate, condenser plates, electrical resistance of tape, electrical resistance of hot wire, time of vaporization from hot wire

(h) optical methods of sorting - scattering from individual particles, scattering from communities of particles, corona rings

(i) microwave scattering method of sorting - radar

(j) sizing by photographic recording - image, streak

(k) television scanning methods of sorting - image, streaks

These methods and techniques to determine drop size-distributions are discussed in Scientific Report No. 1. It was found that many of them were not applicable to automatic counting and sorting. Some techniques were not developed completely and others were designed for manual processing and thereby difficult to develop for automatic application.

It was found that the British have developed and are manufacturing numerous devices for the automatic counting and sorting of small particles. Therefore considerable correspondence ensued to determine if any of the available instruments were usable for particle sizes of 0.5 mm to 5 mm range. Several instruments could be adapted for this particular size range, but is estimated that the cost of the unit would be equal to production costs in America.

Subcontract with University of Michigan

Under a National Science Foundation Grant in 1952, A. Nelson Dingle, who was then an Assistant Professor of Meteorology and Physics at Ohio State University, constructed an optical mechanical spectrograph in cooperation with C. E. Nielsen, Professor of Physics at the Ohio State University. Preliminary studies indicated that little was. known of the ability of this unit to accurately sample raindrop size and distribution. This optical mechanical spectrograph was moved to the University of Michigan when Professor Dingle accepted a new position. Since an evaluation had not been made of the instrument, a subcontract was entered into with the University of Michigan for this purpose with funds totalling $8.590. Numerous trips were made to the University of Michigan to keep in touch with the evaluation. The objectives of the subcontract were to evaluate the performance of the optical mechanical spectrograph, calibrate it to make field observations, and develop field techniques for use of the instrument. The final report on this subcontract, listed at the beginning of this report, discusses the details of the evaluation and its problems. Since there were numerous difficulties, it was concluded that the present unit is still in a developmental stage. It was considered operational by the subcontractor, but there are many ways in which it might be improved. The design and construction of the optical system and the selection of lenses should be reviewed. Since a uniformly illuminated field is required, the selection of lights should be considered. The characteristics of the photo cell with regard to uniformity of response should also be considered in re-designing the optical system and photometer. Consideration of the lens distortion and of the generation of turbulence by the rotating arm of the instrument suggests further modification. The micro-phonics originating in the photometer must be reduced considerably by use of a photometer tube and better mechanical design. Other electronic modifications in the amplifier, discriminator and circuits should receive consideration in another model. Consequently, it appears that before further work is done on the angular scattering technique as proposed by Dingle that another model be built and tested. Further work on the Dingel-Nielsen technique is being supported by another grant from the National Science Foundation.

Drop Camera and Wisconsin Scanner

Another phase of the work was to consider the possibility of adapting the raindrop camera so that photographs might be automatically scanned by a device constructed at the University of Wisconsin. It was found that the highlights or reflections that occur on the raindrop as it is illuminated for photographing seriously handicap the reading of chords which the scanner performs. Consequently laboratory work was done to determine other techniques for lighting of raindrops. One technique was developed whereby the drops could be lighted and the reflection spot would not be evident. The results of this investigation are reported in Appendix A.

Streak Photography

Another method of eliminating the highlight from the reflection of the light on the raindrop would be that of taking a photograph of the drop as it falls past a slit. Through forward lighting of the drop with a black background one could obtain streaks. It is assumed that the streaks are a function of the diameter of the drop. Laboratory work was undertaken and although the results obtained have not been of the quality desired due to the difficulty in producing drops and in the present camera set-up, it appeared that the method was applicable. A Fairchild Strip Camera was obtained from the Air Force to test the feasibility of the idea. A second model was constructed for operation in natural rain. Due to limitation of funds an evaluation was not carried forward. However, it is believed that the method merits further study. By having a photographic record, data are available for further study and evaluation. If the streak method were developed, the film could be scanned automatically to reduce large amounts' of data by a sufficiently accurate and quick method.

Vertical Wind Tunnel

One limitation of many sensing devices is that the sample of precipitation is often too small to be considered typical. It was proposed therefore that a vertical wind tunnel be developed whereby a large volume of sample might be forced past the sampling area in less time than normally occurs. Through consultation with personnel in Fluid Mechanics, analysis and feasibility of the design of a vertical wind tunnel for such an operation indicated that an enormous amount of air would be necessary to keep the drops from coalescing or collecting on the sides of the funnel. It was decided that this addition to a fixed sensing unit, such as an optical spectrograph, did not merit further study.

Condenser Plates

Some work was performed previously, using the change in capacity between parallel plate condensers with the presence of a drop to determine the drop size. One theoretical objection to this technique appeared to be that a non-spherical drop would produce a different capacity change than a spherical drop of the same mass. Some theoretical work was performed in attempting to solve La Place's equation subject to the non-spherical boundary conditions to determine how serious this objection is. Work was not completed due to lack of funds.

CONCLUSIONS AND RECOMMENDATIONS

In Sections 1 through 11 of Scientific Report No. 1, numerous techniques or devices for drop sizing are reported. Those which might be successfully applied to the automatic sizing and counting of natural raindrops are summarized in the following discussion.

The optical method of scanning which utilizes the angular light scattered from individual particles has been employed in a ground-based experimental model by Dingle and the work accomplished indicates that this method of drop-sizing may be successfully developed. Design problems may be such that the tolerances for error, a total of ±15 percent, may be exceeded but it is believed that they would be limited to ±30 percent. This may be the magnitude of the error in sizing individual drops and the error over a sample may be smaller due to the "averaging" effect. The fact that the particles are sized by measuring the height of a pulse leads to calibration problems. An advantage of this system is that it makes possible immediate presentation of data.

A recent translation of an article by Mikirov reports that the Russians have successfully tested an optical method which uses the forward scattered light from a drop in space. Preliminary laboratory tests by the Illinois State Water Survey indicate that the method has considerable promise and a model should be built and tested. The most important advantage of this device is that, by utilizing forward scattering, the magnitude of the scattered light is several times greater. Thus the requirements of the sorter and counter are considerably reduced.

Successful recording of drop images on photographic film has been reported by Jones and Dean. Recently, two similar 30-inch diameter cameras were built for another study by the Illinois State Water Survey. The lower limit of resolution for these cameras is a drop of 0.2 or 0.3 mm diameter. With suitable modification to make the systems compatible and with use of forward lighting of the drops instead of back lighting, film records of drops may be scanned automatically. The most promising scanning device appears to be the one developed at the University of Wisconsin. However, an unknown error would be introduced since the Wisconsin scanner depends on a statistical analysis of chord distributions and the drops are non-spherical.

A method of recording raindrops photographically as streaks has been proposed by Mueller. If this device can be developed successfully, it will be capable of recording drops of 0.1 mm diameter and larger. It should be capable of sizing each drop within a tolerance of ±0.05 mm and a number of drops very accurately as a result of the effect of "averaging". A scanning device, similar to the one developed at the University of Wisconsin, could be used to analyze the data. This type of system would have the disadvantage of not providing an instantaneous presentation of data, but would have the advantage of sizing by measuring the length of a pulse. Problems due to aging of the components are not as severe in this method as in sizing by measuring the height (or intensity) of a pulse. Also, one scanning device may be employed to analyze the data recorded by a network of cameras. Scanning streaks on film appears to be adaptable to a less complicated method of sizing automatically than scanning circular images. Therefore this type of photography is being recommended rather than the type developed by Jones and Dean. One limitation is that the type of distribution obtained would be a "per unit time on unit area" rather than "per unit volume".

The University of Texas has proposed a device for scanning falling drops using a Vidicon tube. If this device can be successfully developed, it promises the following advantages: (1) almost instantaneous presentation of data and (2) a sample of excellent size in 10 seconds. The lower limit of resolution is 0.25 mm drop, and it is expected to size all drops with a tolerance of ±0.125 mm. "Averaging" the errors should have the effect of making the error on a sample (the histogram presentation) somewhat smaller. The tolerances stated are dependent on the resolution of the Vidicon. Other portions of the system may introduce some additional error. This device has the advantage that it sizes by measuring the length of a pulse.

It is believed that the following types of devices listed in order of importance for automatically sizing and counting raindrops are subject to successful development:-

1. Forward scattering of light from individual drops.
2. Photographing streak images and scanning the film as proposed by Illinois State Water Survey.
3. Angular scattering from individual drops as measured by Dingle.
4. Vidicon scanning of streak images as proposed by University of Texas.

APPENDIX A

ILLUMINATION OF HIGHLY REFLECTIVE AND TRANSPARENT SPHERES AS AN AID TO AUTOMATIZED COUNTING

by

R. C. Krump

ABSTRACT

A method of uniform illumination of highly reflective and transparent spheres so that their photographs can be sized and counted by an automatic scanning device is described. Several lighting systems which gave interesting but not entirely satisfactory results are also described. Examples of the photographs obtained by using polished glass beads are presented along with a diagram illustrating the lighting apparatus used In each case.

INTRODUCTION

To obtain photographs of highly reflective and transparent spheres, such as water drops and glass beads, which can be automatically sized and counted, the subjects must be illuminated so that the resulting negatives show images of fairly uniform density against the background.

Shadow images are made by placing the subjects between a camera and a uniform source of light. This method however has not resulted in satisfactory photographs for automatic sizing and counting either of droplets on slides [(1)] or of natural raindrops. [(2)] These photographs are unsatisfactory because the images are dark with a bright spot at the center. The bright spots appear because the central portion of the drop acts as a small lens, concentrating the transmitted light.

DESCRIPTION OF THE TECHNIQUES

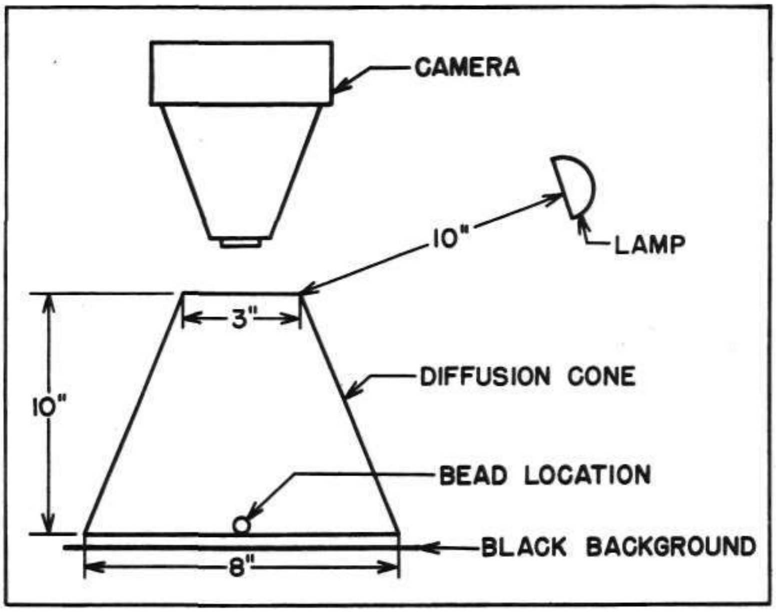
A number of experiments have been made in an attempt to find a suitable method to illuminate droplets for photographing. In these experiments the subjects, glass beads in most cases, have been illuminated from the vicinity of the camera or from the sides. The background was kept dark. One of the reasons for this type of illumination was the dark background can be used in multiple exposure techniques.

Case I—The apparatus shown in Figure 1a consists of a truncated right-circular cone constructed of "Copyrite", which is a frosted celluloid material. The cone was used as a diffusion screen for three 150-watt projector flood lamps, placed slightly above the top edge of the cone. The lamps were evenly spaced radially at about 10 inches from the cone and directed toward the top of the cone.

A photograph taken with this apparatus is illustrated in Figure 1b. The illumination is not uniform, and the contrast - is low. This same set-up was used, varying the location of the flood lamps, with the result that a black spot appeared in the center of the bead, as the lamps were directed farther down the surface of the cone.

Case II—To obtain a diffused light and to eliminate the bright spots, two 12-inch, 32-watt circline fluorescent lamps were used. The lamps were placed 16 inches apart, and the bead was placed midway between their centers, Figure 1c.

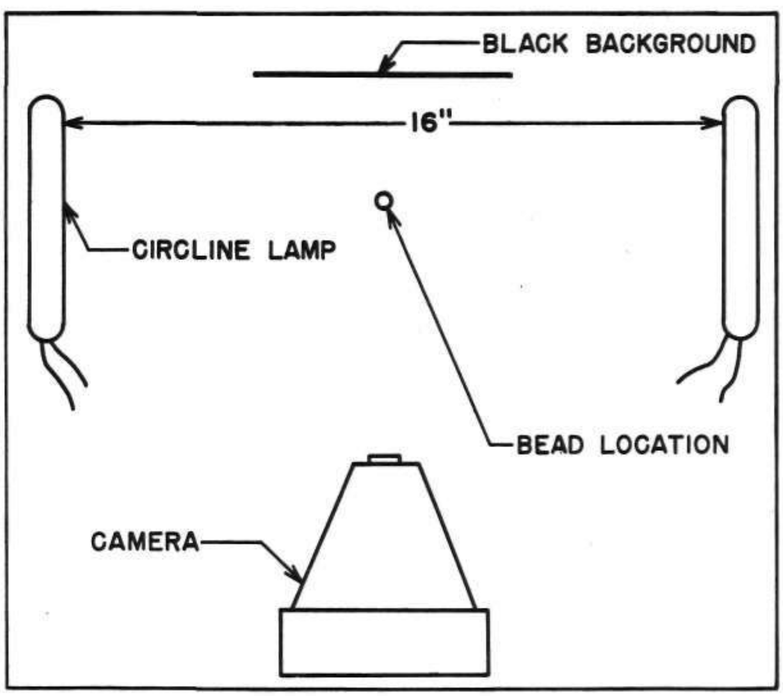
A photograph obtained in this case, Figure 1d, indicates that although the light available from fluorescent lamps is more diffused than from ordinary incandescent lamps, there



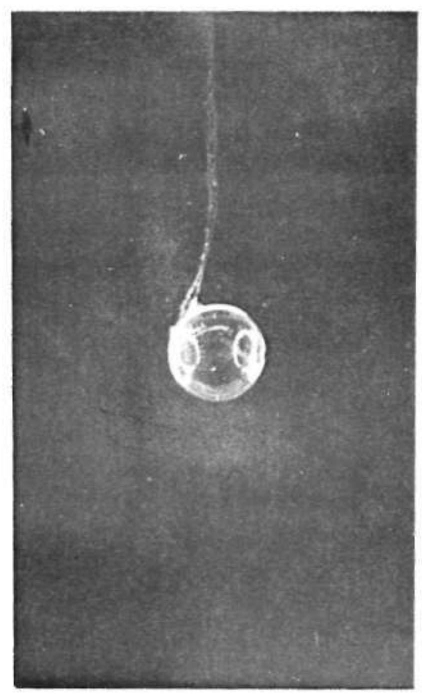
a. SIDE VIEW OF APPARATUS

b. PHOTOGRAPH OF GLASS BEAD

CASE I



c. TOP VIEW OF APPARATUS



d. PHOTOGRAPH OF GLASS BEAD

CASE II

FIG. I CASES I AND II

remains a need for more complete diffusion.

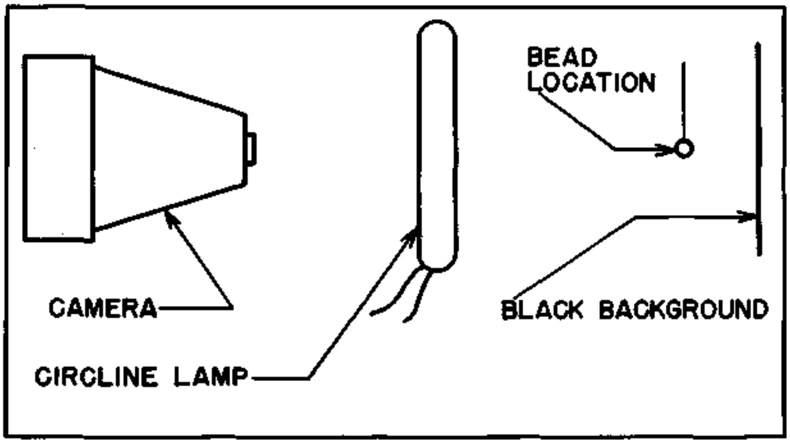
Case III—The apparatus consisted of a single circline lamp identical to those used in Case II. The apparatus was arranged for photographing the glass bead through the center of the lamp, Figure 2a.

Case IV—A screen constructed of two sheets of tracing paper, spaced one inch apart on a wooden frame, was used for diffusion of the light, Figures 2c and 2d. Four 150-watt projector flood lamps were placed five feet from the screen and directed to give uniform illumination over the surface of the screen. A volume 32 inches on a side, surrounding the glass bead, was enclosed with black cloth to prevent unwanted light from falling upon the bead. The glass bead was photographed through a three inch opening in the center of the screen.

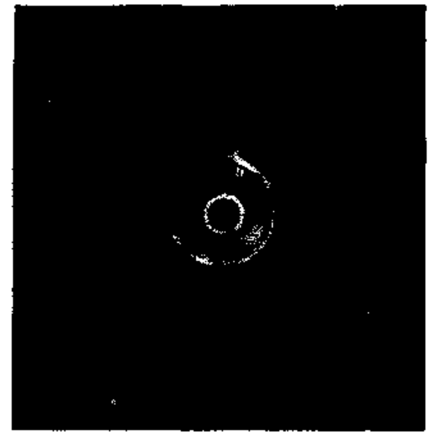
Case V--To obtain a light source at the lens of the camera, a half-silvered mirror was placed in front of the lens at an angle of 45 degrees, Figure 3a. A Number 2 photoflood lamp was directed toward the mirror which reflected the light toward the bead. A photograph was then taken through the mirror, Figure 3b.

Case VI—The apparatus for this case involved the use of a cone, Figure 3c. A six-inch wide opaque washer was placed on the circumference of the large opening of the truncated cone to prevent any direct light from reaching the bead. The lights used in this case were four Number 2 photoflood lamps, which give more intense but less directed light than the projector flood lamps used in previous cases. The cone was made of two thicknesses of "Copyrite" spaced about one-inch apart.

The results of this experiment show that the bead was

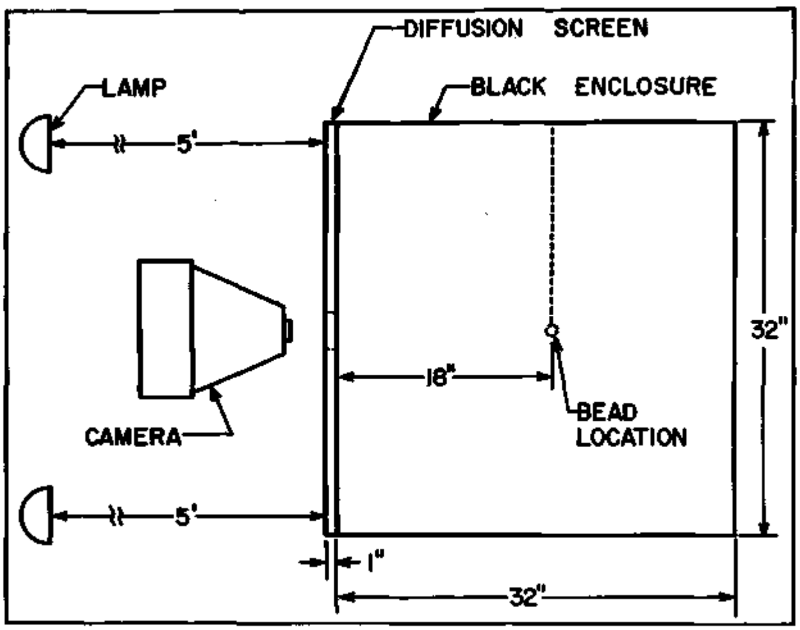


a. SIDE VIEW OF APPARATUS

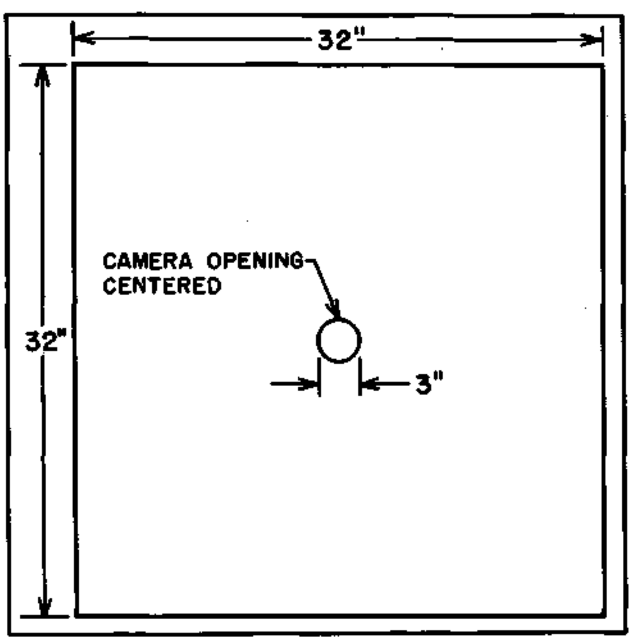


b. PHOTOGRAPH OF GLASS BEAD

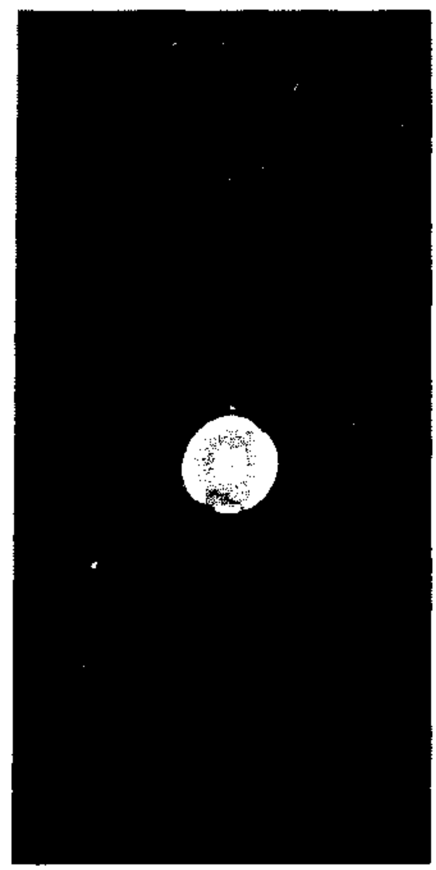
CASE III



c. SIDE VIEW OF APPARATUS



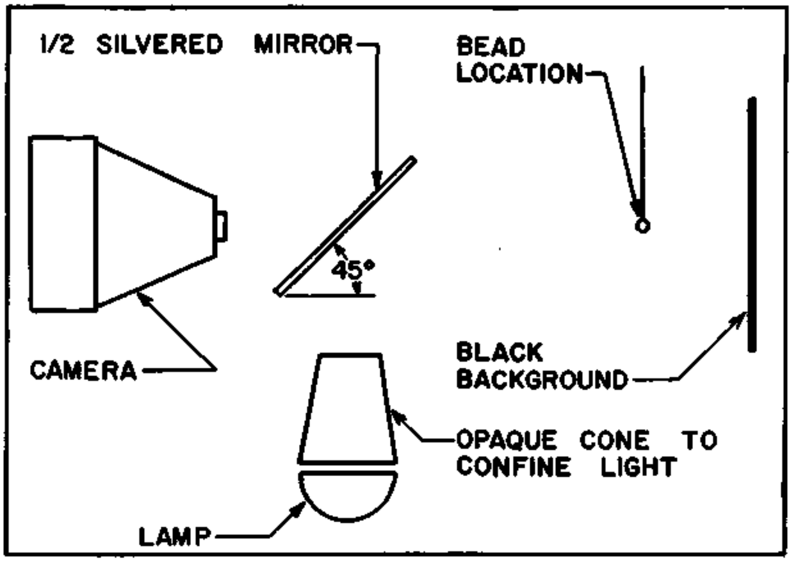
d. FRONT VIEW OF SCREEN



e. PHOTOGRAPH OF GLASS BEAD

CASE IV

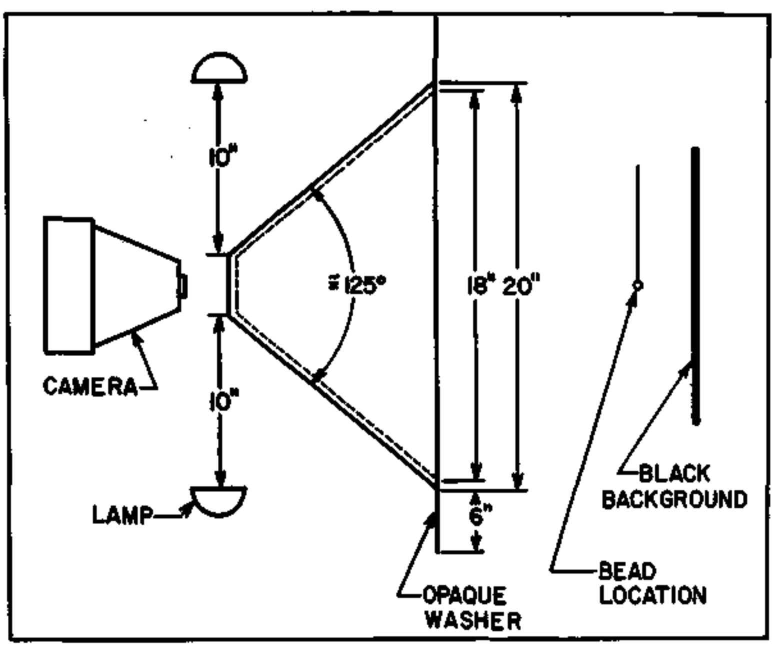
FIG. 2 CASES III AND IV



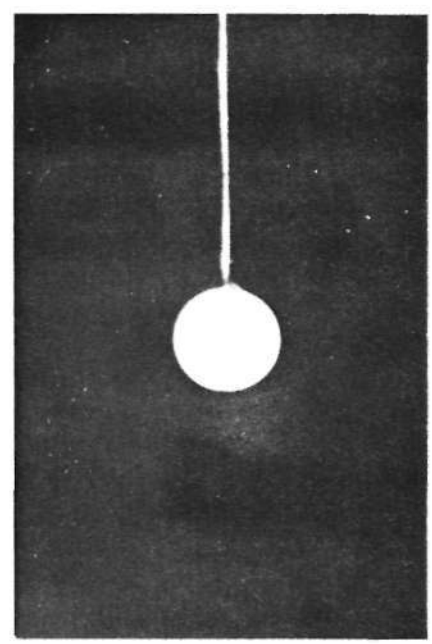
a. SIDE VIEW OF APPARATUS

b. PHOTOGRAPH OF GLASS BEAD

CASE V



c. SIDE VIEW OF APPARATUS



d. PHOTOGRAPH OF GLASS BEAD

CASE VI

FIG. 3 CASES V AND VI

lighted sufficiently to give good contrast and also to give uniform illumination, Figure 3d.

The results by this method compare favorably with those obtained by using a cone with a vertex angle of about 35 degrees. In this case the vertex angle is about 125 degrees, indicating, probably, that a cone with a vertex angle between 35 and 125 degrees would produce favorable results.

Since the bead was positioned on the axis of the cone in Case VI, the results of that case do not indicate the size of the volume that would be properly lighted. It was necessary therefore to vary the distance between the bead and the cone, and also to vary the position of the bead radially with respect to the axis of the cone.

It was observed that the bead would be properly lighted if placed within about three inches of the axis of the cone and within about six inches from the plane of the open end of the cone. These observations were made by taking photographs with the glass bead placed at different positions in the field of light. The size of the properly lighted volume seemed to increase in direct proportion to the increase in the size of the cone.

CONCLUSIONS

The photographs obtained in Cases II and III show rather clearly that a highly polished transparent sphere which is exposed to direct illumination reflects the light source as would a spherical mirror. The photographs obtained in Cases I, IV, and V, while interesting and informative, do not appear to be sufficiently uniform for automatic scanning. However, Case VI did result in a series of photographs which appear suitable for automatic scanning.

REFERENCES

(1) GOLITZINE, N., Method for Measuring the Size of Water Droplets in Clouds, Fogs, and Sprays, Report No. ME-177, Ottawa, Canada, National Research Council of Canada, March.1950.

(2) JONES, D.M.A., and Dean, L. A., A Raindrop Camera, Research Report No. 3, Urbana, Illinois State Water Survey, 1953.

APPENDIX B

USE OP A CYLINDRICAL LENS FOR DROP PHOTOGRAPHY
by

E. A. Mueller

It was proposed by David Atlas during a conference that a cylindrical lens be used in a raindrop photographic set-up in order to compress one dimension of the field of view. It was hoped that by this method, a strip of exposed area on the film would represent a finite volume in space. Measurements would be made only on the undistorted dimension of the drop image to determine the drop diameter.

The usefulness of this technique is obvious. It would permit not only a larger sampling volume for a particular size film but also for a given sampling volume, the diameter on the film which needs to be measured would be larger, that is, have a greater magnification. Secondly, the cylindrical lens has the advantage of producing a means of sampling a volume in space rather than a flat plane as is presently done in the streak photography method. It was hoped that in this way the streak photography could be extended to sample a given volume and still continue to enjoy the advantages of automatic drop counting and sorting. Apparently this may be feasible theoretically, however, it is felt that the loss in contrast may over-weigh the advantage gained by sampling a finite volume.

Use of a cylindrical lens necessitates that the image formed on the film plane will not be in sharp focus for both axes. To illustrate let us assume that the vertical plane, passing through the camera lens and the sampling volume, is the plane in which the curvature of the cylindrical lens is placed. The horizontal axis then, will have no curvature in the cylindrical lens and all points along a horizontal line in the sampling volume will be undisturbed by the cylindrical lens. If the rays passing from a point in the object space and lying in the horizontal plane are focused on the film plane by means of the photographic objective lens, then the introduction of any cylindrical lens will defocus the rays which lie in a horizontal plane from the same point in the object space. This is obvious, since without the cylindrical lens a symmetry exists in the focusing of the rays from the object space in both horizontal and vertical planes. If this is so, and if any effect is to be noted by the introduction of the cylindrical lens, the focus point of the rays in the plane affected by the cylindrical lens will be changed. The introduction of a cylindrical lens introduces astigmatism to the optical system.

The pseudo-image formed by the system with the cylindrical lens will be a sharp focus along the horizontal line in image space but will be blurred in the vertical image space. This blurring in the vertical image space may be used to advantage in that it would extend the drop image vertically and it would simplify registration difficulties in the data processing if measurements are made along horizontal lines in image space.

The elongated pseudo-image may not have a great deal of contrast. Assuming a spherical drop, a normal drop image would be circular. If the drop image is assumed to be uniformly bright, and the image is then elongated by use of the cylindrical lens, loss of contrast would occur. As the image is elongated, the small amount of light or brightness which is available near the extreme horizontal ends of the drop becomes spread out over the vertical extent and the net brightness remaining is greatly reduced. It has been our experience that with drop cameras it is difficult to obtain drop images having sufficient contrast. Any loss of contrast introduced by the optical system should be avoided. Secondly, any system using a cylindrical lens in the method which has been proposed would require that the light for the drops be produced by means of flash tubes and not flood lights.

These difficulties will only be increased by the fact that the elongation necessary in the vertical plane is quite large causing the elongated spherical image to become an elliptical image. The magnification must be so great as to permit measurement through the center of the film image and have the subtended distance at this point essentially equal to the minor diameter of the ellipse. This would require that for a drop which was at the top or bottom of the sampling volume in object space would need to be smeared sufficiently so that the center of the image space has a distance on the image essentially equal to the width of the image if the drop were located in the central portion of the sampling volume. This requires a very strong cylindrical lens and thus the resulting loss in contrast will be rather severe.

In view of the above discussion, it does not appear to be desirable to explore further the use of a cylindrical lens in raindrop photography.

APPENDIX C

RAINDROP AND CLOUD DROPLET SIZING AND COUNTING TECHNIQUES FOR THE USE IN AIRCRAFT

by

J. E. Pearson

Studies of cloud physics and of radar reflectivity have stimulated interest in the size-distribution of raindrops and cloud droplets from the place of their development to the ground. While a few scientists have attempted such studies with balloon-borne equipment; see Cooper, 5-3, Adderley, 5-7 and Fujiwara 7-11 (references refer to "An Evaluation of Raindrop Sizing and Counting Techniques" by Pearson, J. E., and G. E. Martin, Scientific Report No. 1, Contract AF 19 (604)-1900, Illinois State Water Survey, Urbana, Illinois) the majority have utilized instruments in aircraft in flight. Instruments used in aircraft were based on the following principles:—

1. Slides coated with grease or magnesium oxide, exposed for a short interval of time, and photographed. (see 1-29, 1-30, 1-31, 1-33, 1-36, 1-37, 5-9, 7-7, and 7-8).
2. Hacker (see 1-40) collected droplets in a moving oil stream and photographed them.
3. Droplets were collected or frozen on cylinders of various diameters and, by means of collection efficiencies, the size-distribution was determined (see 3-2, 3-3, 3-4, 3-5, and 3-6).
4. Energy of the drops was measured by means of a microphone (see 5-2, 5-5, and 5-7) or by means of sizing the impact on aluminum foil (5-9).
5. Droplets were picked up with an electric probe and sorted by change of electrical characteristics caused by their presence (see 7-7 and 7-8).

6. Light scattering was used to determine drop size (see 8-3, 8-4, 8-5 and 8-15).
7. Droplets were photographed from a moving airplane (see 10-4, 10-6 and the discussion of Streak Photography on page 63).

Serious objections were raised, regarding most of the methods tried, and many of the methods are no longer used. Of the methods tried, two which show the most promise for aircraft are light scattering and streak photography.

The angular light scattering method has undergone extensive development and presently a unit produced by Cornell Aeronautical Laboratory (8-15) is being tested by the Wright Air Development Center. Limited information forthcoming from the tests is favorable. Recent translation from the Russian of an article by Mikirov indicates that the forward light-scattering principle has been developed in Russia. The Russian instrument may overcome some of the problems encountered in the development of the Cornell instrument and the Dingle instrument (8-14).

The streak photography instrument proposed by personnel of the Illinois State Water Survey may be subject to successful development. It appears that if droplets can be photographed as approximately circular images from a moving aircraft (10-4 and 10-6) they should be more readily photographed as streaks. The streak method overcomes objections to the image photography method: excessively fast consumption of film and discontinuity of the record.

It is recommended that the following instruments, in the order named, be considered for development for the purpose of sizing raindrops and cloud droplets from aircraft in flight:

1. Light Scattering
2. Streak Photography

The order above is recommended on the basis that successful developmental work has been done with the light scattering method while streak photography is relatively untried.