TR 170

Technical Report 170

ELECTRICALLY OPERATED IMPACTORS FOR HYDROMETEOR SAMPLING

by

Harold W. O'Brien

and

Motoi Kumai

DECEMBER 1965

U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

Technical Report 170

ELECTRICALLY OPERATED IMPACTORS FOR HYDROMETEOR SAMPLING

by

Harold W. O'Brien

and

Motoi Kumai

DECEMBER 1965

U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

DA Task IVO14501B52A02

PREFACE

This report discusses a portion of the research instrumentation developed since November 1962 in conjunction with USA CRREL project, Fog visibility and snow studies. The work was done under the supervision of Dr. R. W. Gerdel, Chief, Environmental Research Branch, and Mr. James A. Bender, Chief, Research Division.

The impactors described were constructed in USA CRREL's machine shop by personnel of the Measurement Systems Research Branch, Mr. William Parrott, Chief.

USA CRREL is an Army Materiel Command laboratory.

DA Task IV014501B52A31

CONTENTS

ILLUSTRATIONS

SUMMARY

Two models of impactors have been designed for remote sampling of hydrometeors. One, a flashbulb-activated model, is quite suitable for multiple simultaneous sampling, but is prone to occasional mechanical failure. The other, a solenoid-operated model, is almost failure proof but requires considerably more electrical current for multiple simultaneous sampling than does the flash type unit.

Results of some laboratory tests on the impactors are shown and field use of the impactors is discussed.

The appendix contains electrical specifications for each type of unit.

ELECTRICALLY OPERATED IMPACTORS FOR HYDROMETEOR SAMPLING

by

Harold W. O'Brien and Motoi Kumai

INTRODUCTION

The measurement of size and mass distribution of fog and cloud droplets is an important adjunct to studies of visibility and weather modification. The problems of reduced visibility and weather modification have many obvious implications, both military and civil. Methods and techniques for sampling fog droplets have been improved by many scientists: Houghton and Radford (1938), Weickmann and aufm Kampe (1953), Keily (1960), May (1961), Edwards and Evans (1961), and MacCready and Todd (1964). However, an improved type of impactor would be valuable in many phases of the research conducted by the Environmental Research Branch of USA CRREL, including studies of the nucleation and growth of fog and cloud droplets (and crystals), and visibility and weather modification (including fog and cloud dispersion) in cold regions.

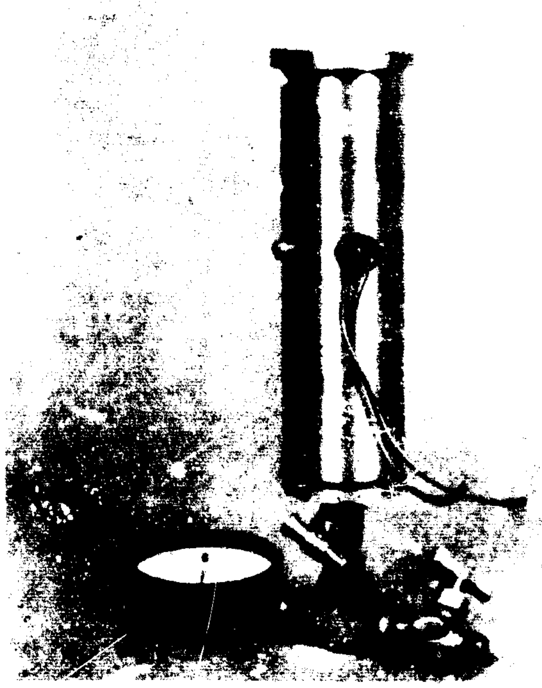
This paper presents a discussion of new electrically-operated hydrometeor samplers of the impactor type which have been designed and subsequently modified by the authors (Fig. 1). These impactors were constructed in the machine shop at USA CRREL and field-tested in Alaska and Greenland. Electrical specifications, given in Appendix A, apply specifically to impactors presently in use at USA CRREL; however, this information may be readily converted, almost in its entirety, to apply to any units of reasonably similar construction.

DESIGN OF THE IMPACTORS

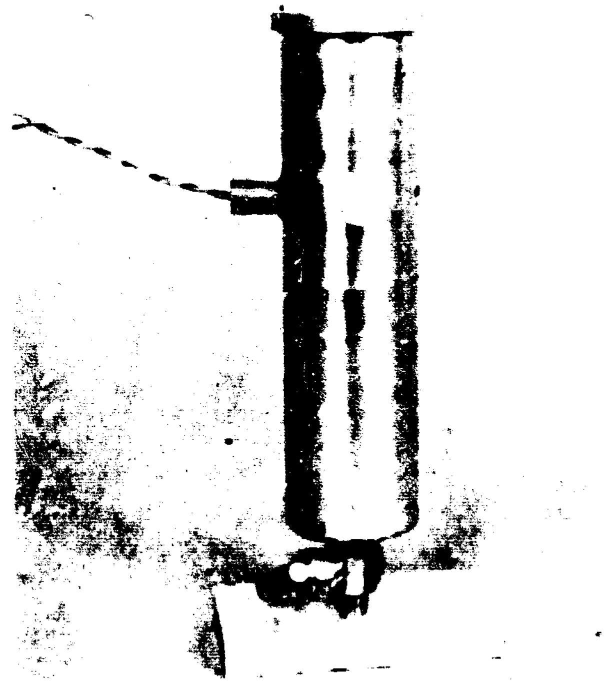
A primary consideration in the design of the new impactors was the desirability of quantitative sampling of fog droplets and ice fog crystals (2μ to 200μ diam) at various heights, e.g., from a tethered blimp or small rocket. The impactors (Fig. 1, 2, 3) consist essentially of a cylindrical set of aluminum chambers, connected in tandem by threaded joints. There are three general types of chambers: impactor stages, valving sections and vacuum chambers. In operation, impinging discs (collector plates) are placed on holders in the impactor stage and the vacuum chamber evacuated. Energizing the valve allows the intake of air through the impactor stage, to equalize the pressure in the vacuum chamber. In passing through the impactor stage, droplets and/or cyrstals impinge upon the collector plates and are collected in a drop of silicone oil or on a sensitized film.

The impactor stages are of relatively conventional design. Each impinging disc holder is machined in the shape of a symmetrical cross with a central portion which is recessed to receive a 10-mm microscope cover glass. The radial ends of the cross and the inner wall of the impactor chamber are threaded so that the distance between impinging disc and intake aperture may be adjusted.

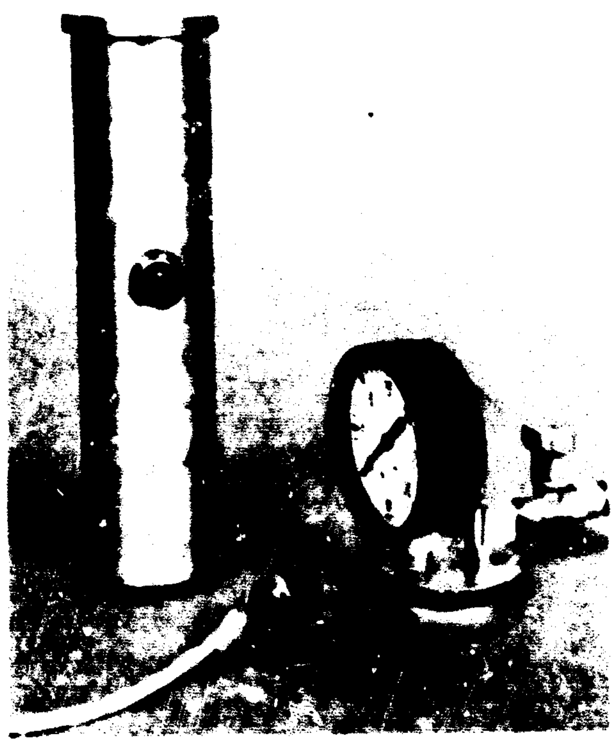
Two types of valving mechanism have been employed in these impactors. The first model (Fig. 1a, 2) has been briefly described in connection with its use in ice fog studies (Kumai and O'Brien, 1965). In this model, the valving chamber is sealed off from the vacuum chamber by a brass diaphragm with a 7-mm hole in its center. Closure of the vacuum chamber is completed by placing a microscope



(a) Original flash type (connected to vacuum gage stand)



(b) Modified flash type (on plain stand).



(c) Solenoid type (requires no stand)

Fig. Electrically operated impactors.

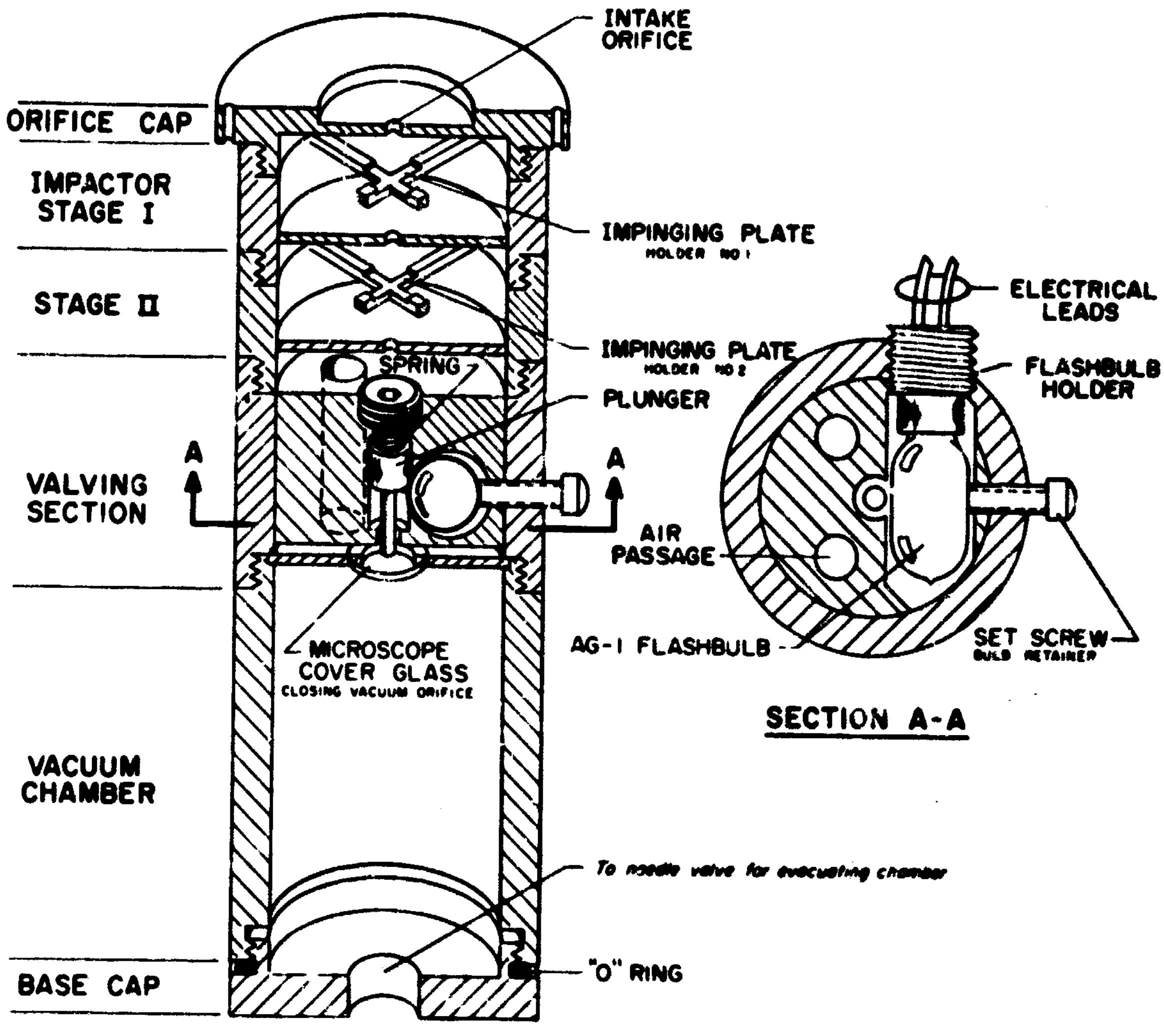


Figure 2. Flash-valve impactor.

cover glass over this hole and sealing it with vacuum grease. The valving device consists of a spring-loaded plunger which, when cocked, is poised above the cover glass which seals the vacuum chamber. The cocked plunger is held in check by an AG-1 flashbulb (with plastic coating removed). Delivery of less than ½ amp to the flashbulb causes the bulb to shatter, releasing the plunger. The plunger pierces the microscope cover glass allowing the intake of air to the vacuum chamber. This type of impactor also requires that the vacuum chamber be fitted with a needle valve through which the chamber may be evacuated. Although unconventional, this valve has one definite advantage: multiple units may be connected in parallel and fired simultaneously* with a very low current. For example, four flash valves could be fired simultaneously at different heights (e.g., 40, 60, 80 and 100 m) with an applied voltage of less than 6.0 volts d c (see App. A). This feature can be important in field research where multiple simultaneous samples are desired but current available at the impactors is low because of long leads, weight restrictions

*Note : This would actually result in a sequential sampling, but would occur so rapidly as to be considered simultaneous for most purposes.

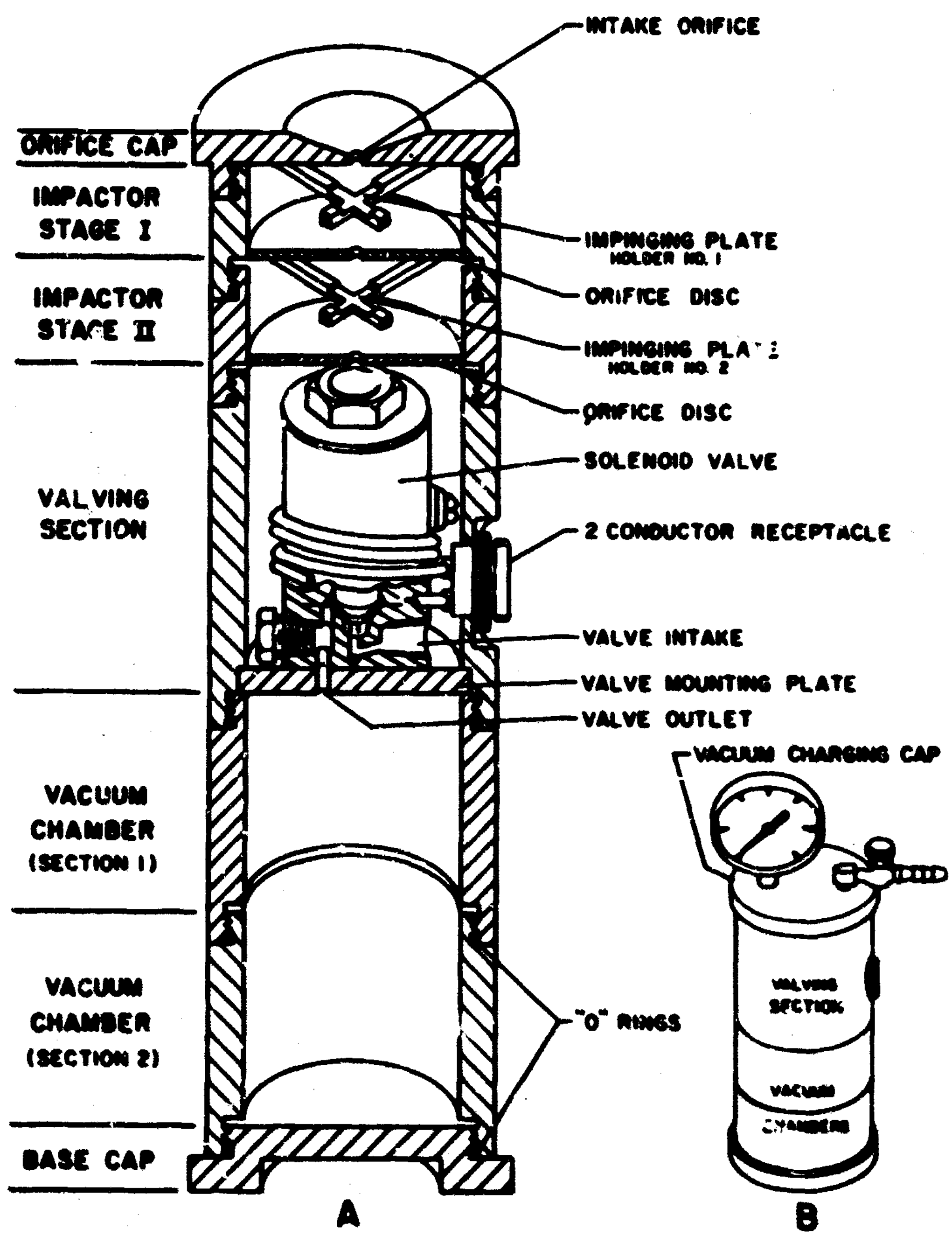


Figure 3. Solenoid impactor.

on wire diameter (as in blimp operations), or limitation to low voltage sources. On the other hand, the flash valve has several undesirable features. One of these is the inconvenience encountered in "reloading" the valve. Also, while using this type of impactor for ice fog studies at Fairbanks, Alaska (Kumai and O'Brien, 1965), and in whiteout dispersal studies at Camp Century, Greenland (Hicks, 1965) it was discovered that particles of burned magnesium ribbon (from the flashbulb filament) may be deposited on the second collector plate (or "impinging disc") even though the flashbulb is semi-isolated from the path of air intake. Apparently there is a "blow-back" at the time of the shattering of the bulb. In addition, the plunger was occasionally jammed by particles of broken glass from the flashbulb, necessitating disassembly and cleaning of the valve.

To eliminate contamination of the sample by particles of burned magnesium from the flashbulb, a revised model of the impactor was designed which utilizes a solenoid valve for releasing the vacuum (Fig. 3a). The solenoid valve is a commercial type, chosen for its compactness and low electrical power requirements. Before installation, the coils were dipped in epoxy for weather-proofing. A mounting plate was designed for the solenoid valve and installed in the valving section. The original valve outlet was plugged and a hole drilled through the mounting plate into the valve to divert the direction of air flow into the vacuum chamber. Naturally, the brass diaphragm containing the vacuum orifice used in the flashbulb units is not necessary in solenoid units and has been eliminated.

Several other modifications were made in the impactors concurrently with the installation of solenoid valves. First, all joints were fitted with O-rings to insure prevention of air leakage. Second, all threaded joints were standardized so that they are freely interchangeable. This enables the use of any combination and number of impactor stages and vacuum chambers. Third, the volume of the vacuum chambers was changed from 100 cm^3 to 50 cm^3 to allow greater flexibility of intake volumes. Fourth, the needle valve was eliminated from the solenoid impactors: a special vacuum charging cap was designed to connect directly to the valving chamber (Fig. 3b) and the chamber is evacuated through the solenoid valve. Finally, the shape of the orifice caps was modified to improve the smoothness of flow through the intake orifice.

The solenoid valve provides cleaner, more convenient operation than the flash units, and in laboratory tests and field research by the authors at Point Barrow, Alaska (Kumai, 1965) and by a research group headed by Mr. J. R. Hicks of USA CRREL at Camp Century, Greenland (Bortell and Hicks, in preparation) there were no cases of failure to operate or of valves becoming jammed. The chief limitation of the solenoid valves is that approximately 0.35 amp is required for each impactor (App. A). Thus, for the example previously cited (four impactors at 40, 60, 80 and 100 m), the solenoid valves would require approximately 32 volts compared to less than 6 volts for the flash units.

IMPACTOR METHODS

The principle of operation of the electrically operated impactors is similar to that of impactors described by Kumai and Francis (1962); their paper may be consulted for a discussion of the collection efficiency of this type of impactor.

Field use of the impactors has previously been discussed at some length (O'Brien and Kumai, 1964). Therefore, only a brief summary of suggested procedures and precautions will be included here.

The most common combination of impactor elements is that shown in Figure 3a, with two impactor stages, one valving section and two 50-cm^3 vacuum chambers. Other combinations may be used; for example, in dense fog one vacuum chamber may be sufficient to draw in a suitable sample.

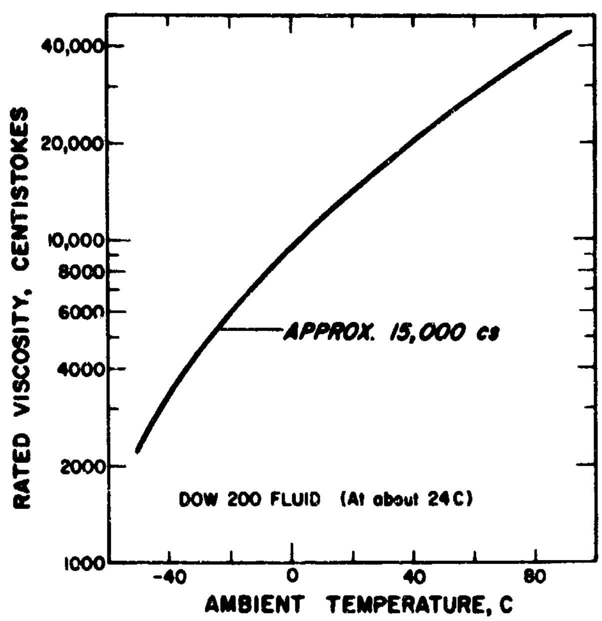


Figure 4. Approximate temperature-viscosity relationship for DOW 200 fluid. For example DOW 200 fluid rated at 9000 cs gives a viscosity of 15,000 cs at about -2C and would probably be suitable for collecting fog droplets at ambient temperatures between -10C and +10C.

Fog droplets (and ice crystals) are usually collected in silicone oil to prevent evaporation (or sublimation). The impinging discs consist of circular microscope cover glasses 10mm in diameter. A glass disc is placed in the recess of each impinging plate holder* and a drop of silicone oil of suitable viscosity is applied to the surface of each disc. The proper oil viscosity is such that the impinging droplets will be suspended in the oil. Our laboratory experiments indicate that a viscosity of about 15,000 centistokes at ambient temperatures is suitable for droplets of fog size. The authors have used DOW 200 fluid, which is available in several viscosities (Fig. 4).

The impactors have also been successfully used in the field by the authors (Point Barrow, Alaska, summer 1964) to impinge fog droplets on chloride-sensitive gelatin film placed on the impinging disc holders (Kumai, 1965).

The vacuum used may be any pressure down to the limit of the pump available. However, experience has shown that the best results are likely to be obtained by using the vacuums shown below with the viscosity of oil recommended (about 15,000 cs at ambient temperatures).

Droplet diam (μ)	Vacuum (in. Hg)
2 - 30	28
10 - 100	14
100 - 200	7

Correctness of vacuum utilized may be checked by examining the sample under a microscope. If the sample (droplets or crystals) appears to be "floating" on the surface of the oil, the degree of vacuum should be increased. If droplets appear to be mostly "flattened" against the glass disc, under the oil, less vacuum is necessary. Ideally, the particles should be suspended in the oil.

In laboratory experiments with the impactors, water droplets having diameters from 2 μ to 200 μ were collected from the mist formed by a spray bottle. Samples

*The impinging disc holders are normally pre-set at an accurately measured distance from the intake aperture (by means of the threaded adjustment previously mentioned) and the collection efficiency of the impactor determined. The position of the disc holder should not be changed thereafter unless the new position is measured with a depth micrometer and recorded so that the collection efficiency may be redetermined.

were collected using impactor vacuums of 28 in. Hg, 14 in. Hg, and 7 in. Hg. At a vacuum of 28 in. Hg (Fig. 5a) droplets smaller than 70 μ were collected and suspended in the silicone oil, whereas large droplets having greater momentum penetrated the film of silicone oil and flattened in the boundary between the glass and the oil (indicated by the arrows in Figure 5a and b). At a vacuum of 7 in. Hg (Fig. 5c) droplets larger than 70 μ were suspended in the silicone oil due to their lower impinging velocity. The collection efficiency for small droplets was much lower at 7 in. Hg than at 28 in. Hg vacuum because their momentum was reduced to such an extent that they could not penetrate the surface of the oil. Consequently, such droplets evaporated rapidly from the surface of the oil.

The size distribution of water droplets in 100 cm^3 of atmosphere is graphically illustrated in Figure 6. (These are the same droplets shown in Figures 5a-c.) The diameter of maximum frequency is the same (10 μ) in each of these three different collections.

Samples of fog having a small droplet size and narrow range of diameters, such as radiation fog, would best be collected using a high vacuum (Fig. 5a). However, samples of fog having a wide size range, such as the marine fogs at Barrow, must be sampled using several different pressures, and appropriate corrections for the collection efficiency must be applied for each degree of vacuum.

Samples should be recovered and photographed as soon as practical after they are obtained, although droplets and/or crystals properly impacted in oil will not evaporate or sublimate, nor will they be absorbed by the silicone oil. If microscopy is to be done in a sheltered place, or if outside with no precipitation, place the disk, oil side up, on a glass microscope slide and place on microscope stage. If microscopy is to be done outside and there is any form of precipitation, place the disk oil side down on the glass slide. Particular care should be taken in this case in focusing the microscope, to identify each glass surface to insure that one recognizes the sample.

For liquid water content measurements, it is imperative that the entire sample on each stage be photographed. This usually will require that several microscope fields be photographed, sometimes at more than one focus setting.

LITERATURE CITED

Bortell, P. and Hicks, J. (in prep) Whiteout modification experiments using ground-based systems, U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL) Special Report 85.

Edwards, G. R. and Evans, L. F. (1961) Cloud droplet sampling technique, Tellus, vol. 13, p. 125-126.

Hicks, J. (1965) Summary of whiteout studies, USA CRREL Technical Report 158.

Houghton, H. and Radford, W. (1938) On the measurement of drop size and liquid water content in fogs and clouds, Papers on Phys. Ocean. Met., M.I.T. and Woods Hole, vol. 6, no. 4, p. 31.

Keily, D. P. (1960) Measurements of drop size distribution and liquid water content in natural clouds, M.I.T., Department of Meteorology, Contract AF 19(604)-3050.

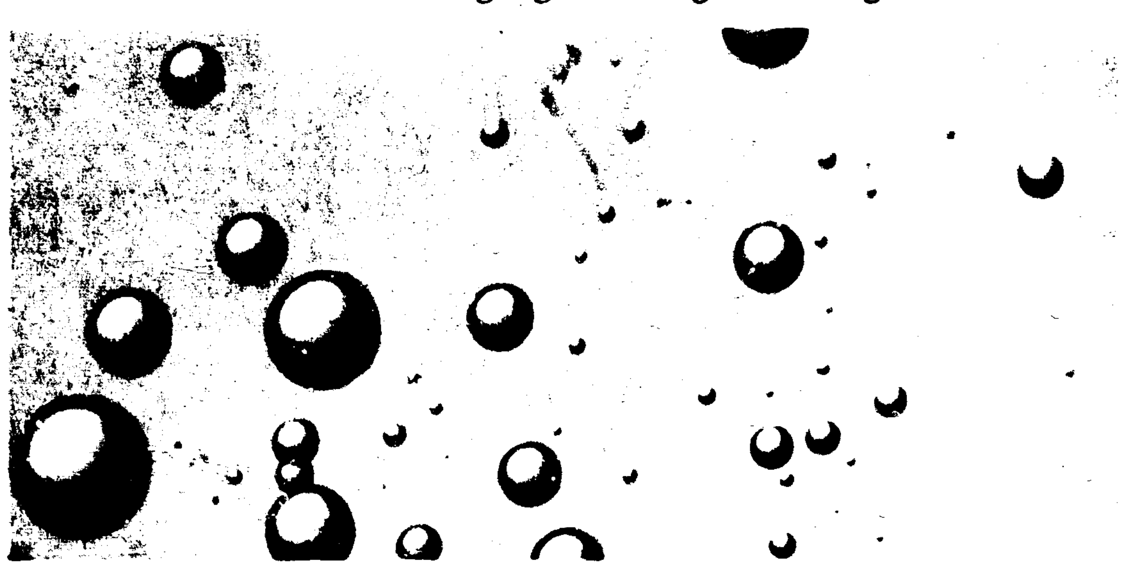
Kumai, M. (1965) The properties of marine air and marine fog at Barrow, Alaska, Paper given at the International Conference on Cloud Physics at Tokyo, Japan.

__________ and Francis, K. E. (1962) Size distribution and liquid water content of fog, northwestern Greenland, USA CRREL Research Report 100.

__________ and O'Brien, H. W. (1965) A study of ice fog and ice-fog nuclei at Fairbanks, Alaska, USA CRREL Research Report 150, Part II.

R61-36 A. Vacuum gauge reading 28 in. Hg. X 75

R61-34 B. Vacuum gauge reading 14 in. Hg. X 75



R61-30 C. Vacuum gauge reading 7 in. Hg. X 75

Figure 5. Water droplets collected in silicone oil of viscosity 15,000 cs at 25C by solenoid valve impactors at different vacuums.

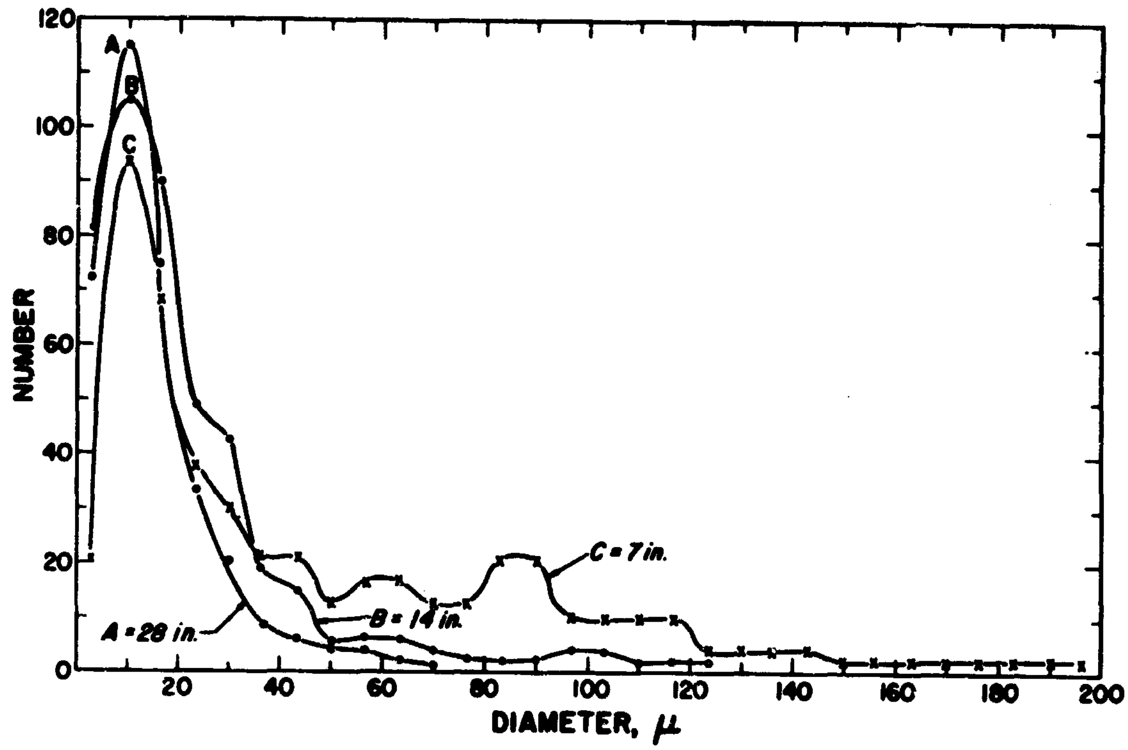


Figure 6. Size distribution of water droplets in 100 cm³ of atmosphere collected by an impactor using 28 in. Hg, 14 in. Hg and 7 in. Hg vacuum.

LITERATURE CITED (Cont'd)

MacCready, P. B., Jr. and Todd, C. J. (1964) Continuous particle sampler, Journal of Applied Meteorology, vol. 3, p. 450-460.

May, K. R. (1961) Fog-droplet sampling using a modified impactor technique, Quarterly Journal of Royal Meteorological Society, vol. 87, p. 535-548.

O'Brien, H. W. and Kumai, M. (1964) Electrically operated impactors for hydrometeor sampling, USA CRREL Technical Note (unpublished).

Weickmann, H. K. and aufm Kampe, H. J. (1953) Physical properties of cumulus clouds, Journal of Meteorology, vol. 10, p. 204.

APPENDIX A. ELECTRICAL SPECIFICATION FOR IMPACTORS

Wire: Recommended wire is 20 gauge copper, Teflon insulated; resistance: 0.009355 ohms/ft.

Valves - Single operation:

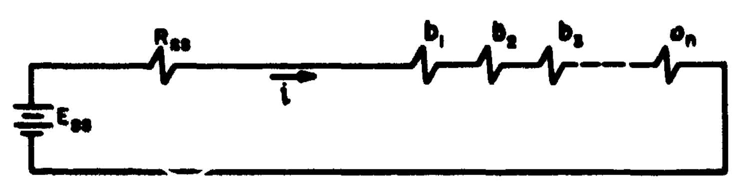
	Flash valve	Solenoid valve
Resistance	1.27 Ω	22 Ω
Minimum current	0.3 amps	0.35 amps

Multiple operation: Multiple operation of the valves for obtaining simultaneous samples from several locations (i.e., several altitudes) is possible. Solenoid units should be connected in SERIES for multiple operation, whereas flash units should be connected ONLY IN PARALLEL.

The voltage required to operate multiple units will depend, of course, on the type and number of impactors, the resistance of the wire, the distance from batteries to impactors, and, in the case of multiple flash units in parallel, the distance between impactors.

Values for both series connected solenoid units and parallel connected flash units are shown in Tables AI through AV. These tables assume that lead wire is as recommended above.

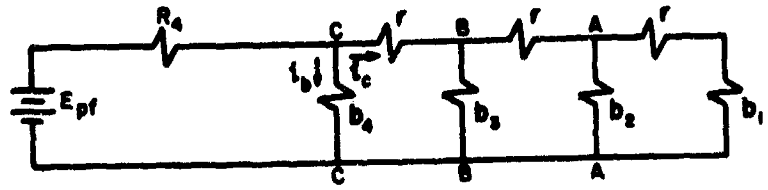
Values for series connected solenoid valves for other combinations of impactors may be computed using the simple circuit diagram:



where E_{ss} is the minimum voltage required for solenoids in series, R_{ss} is the total resistance of the leads of the solenoids in series, n(b) is the total resistance of n solenoid impactors ($b_1 + b_2 + b_3 + \cdots + b_n$), and i is the minimum required current.

$$E_{ss} = i\,(R_{ss} + nb)$$

Values for parallel connected flash valves are a little more complex. As each unit flashes, it opens its branch of the circuit, which requires a recalculation of circuit parameters. The voltage required to fire all impactors depends upon the battery-to-first-impactor distance (D) and upon the distance between impactors (d) (see Fig. A1). A four-impactor circuit is shown below.



i_b 0.3 amps

$b_1 \equiv b_2 \equiv b_3 \equiv b_4 = 1.27$

$V_{cc} = i_b b = 0.381$ volts

$$i_c = \frac{V_{cc}}{r + R_{BB}} = \frac{.381\,(3b^2 + 4rb + r^2)}{b^3 + 6rb^2 + 5r^2 b + r^3}$$

$$E_4 = V_{cc} + R_4\,(i_b + i_c) = 0.381 + R_4\left(0.3 + \frac{0.381\,r^2 + 1.94r + 1.85}{r^3 + 6.35r^2 + 9.69r + 2.05}\right)$$

where E_{pf} is the battery voltage in the parallel flash unit circuit and $E_{(n)}$ is the value of E_{pf} which is required to fire the first of a series of n impactors.

b_4, b_3, b_2 and b_1 represent the resistance of four individual impactor valves.

R_4 is resistance of leads (of length D) to lowest impactor (no. 4) or "resistance to base altitude" (Fig. A_1).

r is resistance of leads (of length d) between impactors (impactors equidistant from each other).

After b_4 has flashed, a three-impactor circuit is present:

$$E_3 = 0.381 + R_3\left(0.3 + \frac{0.968 + 0.381r}{1.615 + 3.82r + r^2}\right)$$

where R_3 = resistance of leads from battery to first unfired impactor remaining in the sequence (or $R_3 = R_4 + r$).

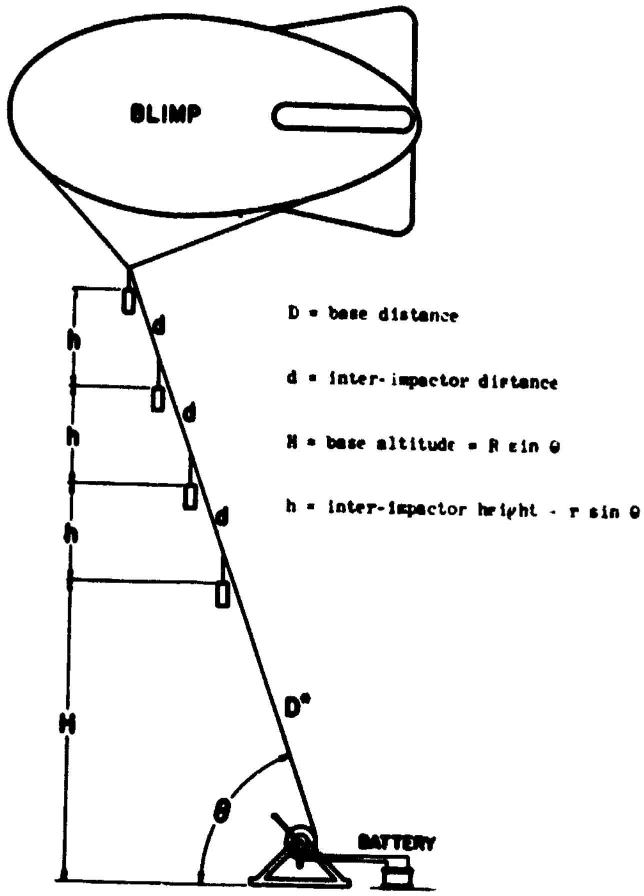
After b_4 and b_3 have flashed, a two-impactor circuit is present, and

$$E_2 \quad 0.381 + R_2\left(0.3 + \frac{0.381}{r + 1.27}\right)$$

where R_2 now equals the resistance from batteries to first unfired impactor (or $R_2 = R_3 + r = R_4 + 2r$) and finally, after b_4, b_3 and b_2 have fired

$$E_1 \quad 0.381 + 0.3\,R_1$$

where R_1 equals the resistance of leads from batteries to remaining impactors (or $R_1 = R_2 + r = R_3 + 2r \quad R_4 + 3r$).



H = base altitude

h = inter-impactor height

D = battery-to-first-impactor distance = H csc θ

d = inter-impactor distance = h csc θ

*The battery is usually placed on the ground (or reel base) under the tethering line so that D extends essentially directly to the ground.

Figure A1. Illustration of the distance parameters involved in calculating voltages for operating impactors from a moored balloon (blimp).

E_4, E_3, E_2 and E_1 can be used to determine the voltage required to fire the first of 4, 3, 2 or 1 impactors in parallel. In each case, however, in calculating minimum required voltages for a given number of impactors, calculations must also be made for each successive stage as impactors cut out of the circuit, i.e., in the example given, E_4, E_3, E_2 and E_1 must be compared and the largest value of voltage will be the minimum voltage required to fire the entire sequence of impactors. This is necessary because, as the distance between impactors increases with respect to the base distance, the division of current between impactors shifts with sequential firing so that the maximum voltage may be required during firing of an intermediate impactor instead of being determined by either the initial or final firing conditions.

Table AI. Minimum voltages, solenoid units in SERIES. Base distance D and inter-impactor distance d in feet or in meters as specified

		No. of solenoid units (n)			
		1	2	3	4
		volts	volts	volts	volts
D + Σd ↓	0	7.7	15.4	23.1	30.8
	5m	7.8	15.5	23.2	30.9
	10m	7.9	15.6	23.3	31.0
	50'	8.0	15.7	23.4	31.1
	20m	8.1	15.8	23.5	31.2
	30m	8.3	16.0	23.7	31.4
	100'	8.4	16.1	23.8	31.5
	40m	8.5	16.2	23.9	31.6
	150'	8.7	16.4	24.1	31.8
	50m	8.8	16.5	24.2	31.9
	200'	9.0	16.7	24.4	32.1
	100m	9.1	16.8	24.5	32.2
	150m	10.9	18.6	26.3	34.0
	500'	11.0	18.7	26.4	34.1
	200m	12.0	19.7	27.4	35.1
	1000'	14.3	22.0	29.7	37.4
	1500'	17.5	25.2	32.9	40.6
	2000'	20.8	28.5	36.2	43.9

Table AII. Minimum voltages, single flash unit. Base distance D in feet or in meters as specified.

		d = 0
D ↓	0	0.38
	10'	0.44
	10m	0.56
	100'	0.94
	50m	1.3
	200'	1.5
	100m	2.2
	150m	3.1
	500'	3.2
	200m	4.1
	750'	4.6
	1000'	6.0
	1250'	7.4
	1500'	8.8
	1750'	10.2
	2000'	11.6

Table AIII. Minimum voltages, two flash units in PARALLEL. Base distance D and inter-impactor distance d in feet unless meters is specified.

d / D	0	1m	5	2m	10	15	5m	20	25	30	10m	40	50	20m	75	100	200	500	1000
0																			6.0
200								LESS THAN 6.0 VOLTS											7.1
100m	4.1																		7.8
150m	6.0																	5.9	8.8
500	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.2	5.1	5.1	4.9	4.8	4.6					6.0	8.8
200m	7.7	7.6	7.5	7.3	7.1	7.0	6.9	6.7	6.6	6.5	6.3	6.2	6.0	5.8	5.6			6.9	9.7
750	8.8	8.6	8.6	8.4	8.3	8.0	8.0	7.9	7.7	7.5	7.4	7.2	7.0	6.8	6.6	6.3	5.7	7.4	10.2
1000	11.6	11.4	11.3	11.1	10.9	10.6	10.5	10.4	10.1	9.9	9.8	9.5	9.2	8.9	8.7	8.3	7.4	8.8	11.6
1250	14.4	14.1	14.0	13.8	13.5	13.1	13.0	12.9	12.5	12.3	12.1	11.8	11.4	11.0	10.8	10.3	9.1	10.2	13.0
1500	17.2	16.9	16.7	16.4	16.1	15.7	15.5	15.4	14.9	14.6	14.5	14.0	13.6	13.1	12.8	12.2	10.9	11.6	14.4
1750	20.0	19.6	19.5	19.1	18.8	18.2	18.1	17.9	17.4	17.0	16.8	16.3	15.8	15.3	14.9	14.2	12.6	13.0	15.8
2000	22.8	22.4	22.2	21.8	21.4	20.8	20.6	20.4	19.8	19.4	19.2	18.6	18.0	17.4	17.0	16.2	14.4	14.4	17.2

Table AIV. Minimum voltages, two flash units in PA[illegible]LEL. Base distance D and inter-impactor distance d in feet unless meters is specified.

d / D	0	1m	5	2m	10	15	5m	20	25	30	10m	40	50	20m	75	100	200	500	1000
0						LESS THAN 6.0 VOLTS												6.0	11.6
200																		7.1	12.7
100m	5.9	5.4	5.4	5.2	4.9	4.6	4.5	4.4	4.1									7.8	13.4
150m	8.6	7.9	7.9	7.6	7.1	6.7	6.5	6.4	6.0									8.8	14.0
500	8.7	8.0	8.0	7.7	7.2	6.8	6.6	6.5	6.1	5.9	5.7	5.5	5.2	5.2	5.2	5.1	5.4	8.8	14.4
200m	11.3	10.4	10.4	10.0	9.4	8.8	8.6	8.4	7.9	7.6	7.4	7.1	6.7	6.5	6.5	6.4	6.4	9.7	15.3
750	12.9	11.9	11.8	11.4	10.7	10.1	9.8	9.5	8.9	8.6	8.4	8.0	7.7	7.3	7.2	7.1	7.0	10.2	15.8
1000	17.1	15.7	15.6	15.1	14.1	13.3	12.9	12.6	11.8	11.4	11.1	10.6	10.1	9.5	9.3	9.1	8.8	11.6	17.2
1250	21.3	19.5	19.4	18.8	17.5	16.5	16.0	15.6	14.6	13.8	13.8	13.1	12.5	11.8	11.4	11.0	10.5	13.0	18.6
1500	25.4	23.3	23.2	22.4	20.9	19.7	19.1	18.7	17.5	16.9	16.4	15.7	14.9	14.0	13.5	13.0	12.3	14.4	20.0
1750	29.6	27.2	27.0	26.1	24.4	23.0	22.3	22.2	20.3	19.6	19.1	18.2	17.4	16.3	15.6	15.0	14.0	15.8	21.4
2000	33.8	31.0	30.8	29.8	27.8	26.2	25.4	24.8	23.2	22.4	21.8	20.8	19.8	18.6	17.8	17.0	15.8	17.2	22.8

Table AV. Minimum voltages, four flash units in PARALLEL. Base distance D and inter-impactor distance d in feet unless meters is specified.

d / D	0	1m	5	2m	10	15	5m	20	25	30	10m	40	50	20m	75	100	200	500	1000
0										LESS THAN 6.0 VOLTS								8.8	17.2
200	4.9	4.9	4.5	4.3	4.1	3.9												9.9	18.3
100m	7.8	7.8	7.1	6.8	6.5	6.2	5.5	5.5	4.8	4.5	4.5	4.2					5.6	10.6	19.1
150m	11.5	11.5	10.5	10.0	9.5	9.0	8.1	8.1	7.1	6.6	6.6	6.1				6.0	6.7	11.6	20.0
500	11.7	11.7	10.7	10.2	9.7	9.2	8.2	8.2	7.2	6.7	6.7	6.2	5.7	5.7	5.8	6.1	6.3	11.6	20.0
200m	15.2	15.2	13.9	13.3	12.6	11.9	10.6	10.6	9.3	8.6	8.6	8.0	7.3	7.1	7.2	7.3	7.9	12.5	20.9
750	17.3	17.3	15.8	15.1	14.3	13.6	12.1	12.1	10.6	9.8	9.8	9.1	8.3	7.9	7.9	8.1	8.5	13.0	21.4
1000	22.9	22.9	21.0	20.0	18.6	18.0	16.0	16.0	14.0	13.0	13.0	12.0	11.0	10.0	10.0	10.1	10.3	14.4	22.8
1250	28.6	28.6	25.8	24.9	23.6	22.4	20.0	20.0	17.4	16.1	16.1	14.9	13.6	12.4	12.4	12.1	12.1	15.8	24.2
1500	34.3	34.3	31.3	29.8	28.3	26.8	23.8	23.8	20.8	19.3	19.3	17.8	16.3	14.8	14.8	14.2	13.9	17.2	25.6
1750	39.9	39.9	36.4	34.7	32.6	31.2	27.7	27.7	24.2	22.4	22.4	20.7	18.9	17.2	17.2	16.2	15.6	18.6	27.0
2000	45.6	45.6	41.6	39.6	37.6	35.6	31.6	31.6	27.6	25.6	25.6	23.6	21.6	19.6	19.6	18.2	17.4	20.0	28.4

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP

3. REPORT TITLE

ELECTRICALLY OPERATED IMPACTORS FOR HYDROMETEOR SAMPLING

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Technical Report

5. AUTHOR(S) (Last name, first name, initial)

O'Brien, Harold W., and Kumai, Motoi

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
Dec 65	19	12

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report 170
b. PROJECT NO.	
c. DA Task IV014501B52A02	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Cold Regions Research and Engineering Laboratory

13. ABSTRACT

Two models of impactors have been designed for remote sampling of hydrometeors. One, a flashbulb-activated model, is quite suitable for multiple simultaneous sampling, but is prone to occasional mechanical failure. The other, a solenoid-operated model, is almost failure proof but requires considerably more electrical current for multiple simultaneous sampling than does the flash type unit. Results of some laboratory tests on the impactors are shown, and field use of the impactors is discussed. The appendix contains electrical specifications for each type of unit.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Meteorological instruments						
Precipitation--Measurement						
Hydrometeors--Measurement						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ______."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ______."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ______."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

Unclassified