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WADC TECHNICAL REPORT 53-48

PRELIMINARY REPORT ON THE ICING INTENSITY DATA OBTAINED IN FLIGHTS THROUGH NATURAL ICING CLOUDS (1 December 1952 to 31 December 1952)

Robert E. Blatz
Bernard J. Brown

Aeronautical Icing Research Laboratory
Smith, Hinchman & Grylls, Inc.

March 1953

WRIGHT AIR DEVELOPMENT CENTER

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Directorate of Flight and All Weather Testing
Contract No. AF 33(600)-8114
RDO No. 560-74

Wright Air Development Center
Air Research and Development Command
United States Air Force
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FOREWORD

This report was prepared by the Aeronautical Icing Research Laboratories of Smith, Hinchman & Grylls, Inc. in partial fulfillment of the requirements of Contract AF 33(600)-8114. The Aeronautical Icing Research Laboratories are performing research and development work on aircraft icing problems under the research and development contract identified by Research and Development Order No. 560-74. This program is administered under the direction of the Icing Unit, Engineering Branch, Directorate of Flight and All-Weather Testing, Wright Air Development Center, with Mr. R. J. Hawn as the Project Engineer. The report is one of a series to be issued.

Capts. F. G. Bastian and W. E. Archer, of the Wright Air Development Center, were the pilots of the airplane utilized to compile the icing data presented in the report.

ABSTRACT

The meteorological data obtained by the Willow Run Laboratory of the Aeronautical Icing Research Laboratories, during icing flights in December 1952, are presented. A total of eight icing flights were made with a B-24 airplane. During these icing flights fifty-six icing-intensity measurements were obtained by the rotating multi-cylinder method.

The data presented consists of liquid water content, mean effective droplet diameter, droplet-distribution type, free-air temperature, pressure altitude, true airspeed, type of cloud and geographical location. The range of the meteorological conditions encountered during this period is as follows: liquid water content of .06 to .68 gms/m^3; mean effective droplet diameter of 4 to 17 microns; free-air temperature of +10 to +28 ^oF and pressure altitude of 3500 to 6300 feet.

Frequency-of-occurrence curves for liquid water content, mean effective droplet diameter and free-air temperature are presented.

PUBLICATION REVIEW

The publication of this report does not constitute approval by the Air Force of the findings or the conclusions contained therein. It is published only for the exchange and stimulation of ideas.

H. B. MANSON, JR.
Colonel, USAF
Director of Flight and All-Weather Testing

PRELIMINARY REPORT ON THE ICING INTENSITY DATA OBTAINED IN FLIGHTS THROUGH NATURAL ICING CLOUDS (1 December 1952 to 31 December 1952)

INTRODUCTION

This report, requested by The Directorate of Flight and All-Weather Testing (WCTEW-4), WADC, contains the data on the measurement of the meteorological variables encountered during flights through natural icing conditions. These data were obtained by the Aeronautical Icing Research Laboratory, Willow Run, Michigan.

The major portion of the flight data presented in tabular form in this report was obtained in conjunction with the flight requirements of concurrent engineering projects. These flights were not intended primarily to make meteorological investigations of the icing conditions encountered, however, the type of cloud formations, the geographical locations and other flight variables were recorded during the icing encounters. This information has been included in the data tables along with the icing intensity data.

The measurement of the icing intensity was obtained with a rotating multi-cylinder unit. With this instrument the liquid water content, mean effective droplet diameter and the droplet size distribution can be determined.

The range of meteorological conditions encountered during the icing period covered in this report is presented in the following table:

	MAX.	MIN.
Liquid Water Content, gms/m^3	.68	.06
Mean-Droplet Size, microns	17	4
Temperature, ^oF	+28	+10
Pressure Altitude, ft.	6300	3500

EQUIPMENT AND PROCEDURE

The aircraft employed for the flights was an EB-24M bomber type airplane, equipped with a thermal anti-icing system. Flight procedures varied with existing weather conditions, traffic control problems and the requirements of concurrent engineering flight projects.

The rotating multi-cylinder array in use for all flights consisted of six cylinders with diameters of 1/8, 5/16, 1/2, 1-1/4, 1-3/4 and 3 inches. The exposed length of the 1/8 inch diameter cylinder was 12.7 cm. while all remaining cylinders were 10 cm. in length.

RESULTS AND DISCUSSION

The flight meteorological data for the period covered by this report are summarized in Table I. A total of eight flights were conducted during which icing conditions were encountered and the accumulated total of multi-cylinder runs was fifty-six. The data for five of these runs could not be matched to the theoretical KØ curves and in three instances the icing conditions were intermittent during the cylinder exposure time. The runs thus affected are labeled with appropriate notations in the remarks column of Table I.

Figures 1, 2 and 3 contain curves showing frequency of occurrence of liquid water content, mean effective droplet diameter and ambient air temperatures respectively. For an assumed icing condition of .5 gms/m^3, 15 microns and +15 °F, the curves show that:

1. 94% of the measured values of liquid water content were equal to or less than .5 gms/m^3,

2. 95% of the measured values of the mean effective droplet diameters were equal to or less than 15 microns,

3. For 42% of the icing encounter, the measured ambient air temperature was +15 °F or lower. The minimum temperature recorded was +10 °F.

The discontinuity of the curve in Figure 3 indicates that insufficient data were obtained during the period covered by this preliminary report to provide a satisfactory frequency curve. A final report will be published at the completion of the 1952-1953 icing season which will include the data for all icing flights.

To show the variation of liquid water content with droplet size and ambient air temperature, Figures 4 and 5 were prepared. Figure 4 contains the plot of liquid water content versus mean effective droplet diameters. Figure 5 shows the variation of liquid water content with ambient air temperature as measured during the exposure time of the multi-cylinder units.

DATE	FLT	TIME (EST)	TRUE AIR-SPEED (mph)	PRES-SURE ALTI-TUDE (ft)	TEM-PERA-TURE (°F)	LIQUID WATER CONTENT (g/m^3)	MEAN-EFFECTIVE DROPLET DIAMETER (microns)	DROPLET SIZE DISTRI-BUTION	CLOUD TYPE	LOCATION	REMARKS
1952 12-11	1	1131	179	5,000	14	.18	10	B	St. Cum.	35 miles NW. of Windsor, Ont.	Inter-mittent
		1139	182	5,000	14	.08	9	B		10 miles SE. of Flint	
		1148	178	5,000	12	.33	12	E		10 miles NW. of Flint	
		1158	178	5,000	12	.58	14	A		20 miles SE. of Saginaw	
		1213	178	5,000	12	.35	12	A		Over Gladwin	
		1226	172	5,000	11	.32	12	D		5 miles N. of Saginaw	
12-11	2	1444	178	4,060	18	.22	10	C	St. Cum.	N. of Salem	
		1458	177	4,100	17	.26	10	D		Over Flint	
		1507	178	5,000	13	.33	11	D		25 miles SW. of Saginaw	
		1517	178	5,000	11	.52	15	A		20 miles NW. of Saginaw	
		1545	178	5,000	15	.60	13	D		15 miles NW. of Flint	
		1557	178	5,000	13	.68	12	A		12 miles N. of Dunham Lake	

TABLE I

SUMMARY OF FLIGHT ICING INTENSITY DATA OBTAINED

BY THE ROTATING MULTI-CYLINDER METHOD

DURING DECEMBER 1952

DATE	FLT	TIME (EST)	TRUE AIR-SPEED (mph)	PRES-SURE ALTI-TUDE (ft)	TEM-PERA-TURE (°F)	LIQUID WATER CONTENT (g/m^3)	MEAN-EFFECTIVE DROPLET DIAMETER (microns)	DROPLET SIZE DISTRI-BUTION	CLOUD TYPE	LOCATION	REMARKS
1952 12-19	1	1238	208	3,500	17	.22	9	D	St. Cum.	20 miles W. of Grand Marais	
		1245	203	3,500	18	.23	12	D		Over Grand Marais	
		1306	203	3,500	19	.23	11	A		Over Grand Marais	
		1313	171	3,500	12	.27	11	B		35 miles E. of Houghton	
		1323	171	3,500	10	.28	11	A		10 miles E. of Houghton	
		1425	183	3,700	19					40 miles NW. of Traverse City	Unable to match KØ curve
		1429	183	3,700	17	.09	10	A		40 miles NW. of Traverse City	
		1435	183	3,800	16	.20	11	A		45 miles NW. of Traverse City	
12-22	1	1516	169	6,000	28	.30	14	B	St. Cum.	25 miles W. of Grand Rapids	
		1528	206	6,000	24	.30	7	J		15 miles W. of Muskegon	
		1535	195	6,000	24					40 miles E. of Milwaukee	Unable to match KØ curve

TABLE I - CONTINUED

DATE	FLT	TIME (EST)	TRUE AIR-SPEED (mph)	PRES-SURE ALTI-TUDE (ft)	TEM-PERA-TURE (°F)	LIQUID WATER CONTENT (g/m^3)	MEAN-EFFECTIVE DROPLET DIAMETER (microns)	DROPLET SIZE DISTRI-BUTION	CLOUD TYPE	LOCATION	REMARKS
1952 12-22	1	1612	203	6,000	24	.30	14	J	St. Cum.	35 miles E. of Milwaukee	
		1617	202	6,000	24	.21	13	J		30 miles W. of Muskegon	
		1625	199	6,000	24	.27	13	J		Over Muskegon	
		1636	195	6,000	24	.30	16	A		5 miles NW. of Grand Rapids	
		1648	192	6,300	24					25 miles E. of Grand Rapids	Unable to match KØ curve
		1706	199	6,300	28					5 miles W. of Lansing	Unable to match KØ curve
12-26	1	1225	209	3,500	25				St. Cum.	Over Saginaw	Unable to match KØ curve
		1308	206	4,000	25	.17	13	A		Over Traverse City	
		1324	204	4,000	25	.27	8	F		Over Cadillac	
		1336	212	4,000	25	.10	8	A		60 miles S. of Cadillac	

TABLE I - CONTINUED

DATE	FLT	TIME (EST)	TRUE AIR-SPEED (mph)	PRES-SURE ALTI-TUDE (ft)	TEM-PERA TURE (°F)	LIQUID WATER CONTENT (g/m^3)	MEAN-EFFECTIVE DROPLET DIAMETER (microns)	DROPLET SIZE DISTRI-BUTION	CLOUD TYPE	LOCATION	REMARKS
1952 12-26	1	1346	210	4,000	25	.17	9	A	St. Cum.	30 miles N. of Grand Rapids	
		1354	208	4,000	25	.10	10	A		Over Grand Rapids	Inter-mittent
12-29	1	1401	198	4,000	17	.33	9	C	St. Cum.	10 miles S. of Pellston	
		1409	198	4,000	15	.18	12	B		5 miles N. of Pellston	
		1417	197	4,000	14	.22	8	E		30 miles N. of Pellston	
		1428	200	4,000	12	.25	11	C		15 miles W. of Sault Ste. Marie	
		1440	209	3,900	10	.18	12	A		20 miles E. of Grand Marais	
		1449	199	3,800	12	.28	13	D		15 miles E. of Grand Marais	
		1504	189	4,000	11	.23	12	E		20 miles E. of Grand Marais	
		1516	199	4,000	12	.27	9	E		30 miles W. of Sault Ste. Marie	
		1525	199	4,000	11	.23	7	E		Over Sault Ste. Marie	

TABLE I - CONTINUED

DATE	FLT	TIME (EST)	TRUE AIR-SPEED (mph)	PRES-SURE ALTI-TUDE (ft)	TEM-PERA TURE (°F)	LIQUID WATER CONTENT (g/m^3)	MEAN-EFFECTIVE DROPLET DIAMETER (microns)	DROPLET SIZE DISTRI-BUTION	CLOUD TYPE	LOCATION	REMARKS
1952 12-29	1	1535	202	4,000	15	.13	12	B	St. Cum.	20 miles S. of Sault Ste. Marie	
		1545	202	4,000	16	.36	17	B		Over Pellston	
		1557	198	3,900	17	.19	15	B		40 miles S. of Pellston	
12-31	1	1402	198	4,000	21	.20	10	C	St. Cum.	Over Grand Rapids	
		1416	206	4,000	17	.26	4	F		35 miles S. of Grand Rapids	
		1434	205	3,600	17	.06	9	A		10 miles S. of Cadillac	
		1508	202	3,700	15	.16	9	A		25 miles S. of Cadillac	Inter-mittent
		1518	201	4,000	17	.19	9	A		45 miles N. of Grand Rapids	
		1527	203	4,000	17	.19	10	A		20 miles N. of Grand Rapids	
		1539	204	4,000	17	.30	12	B		20 miles E. of Grand Rapids	
		1547	201	4,000	17	.28	10	A		5 miles W. of Lansing	
		1557	200	4,000	17	.35	12	B		25 miles E. of Lansing	

TABLE I - CONTINUED

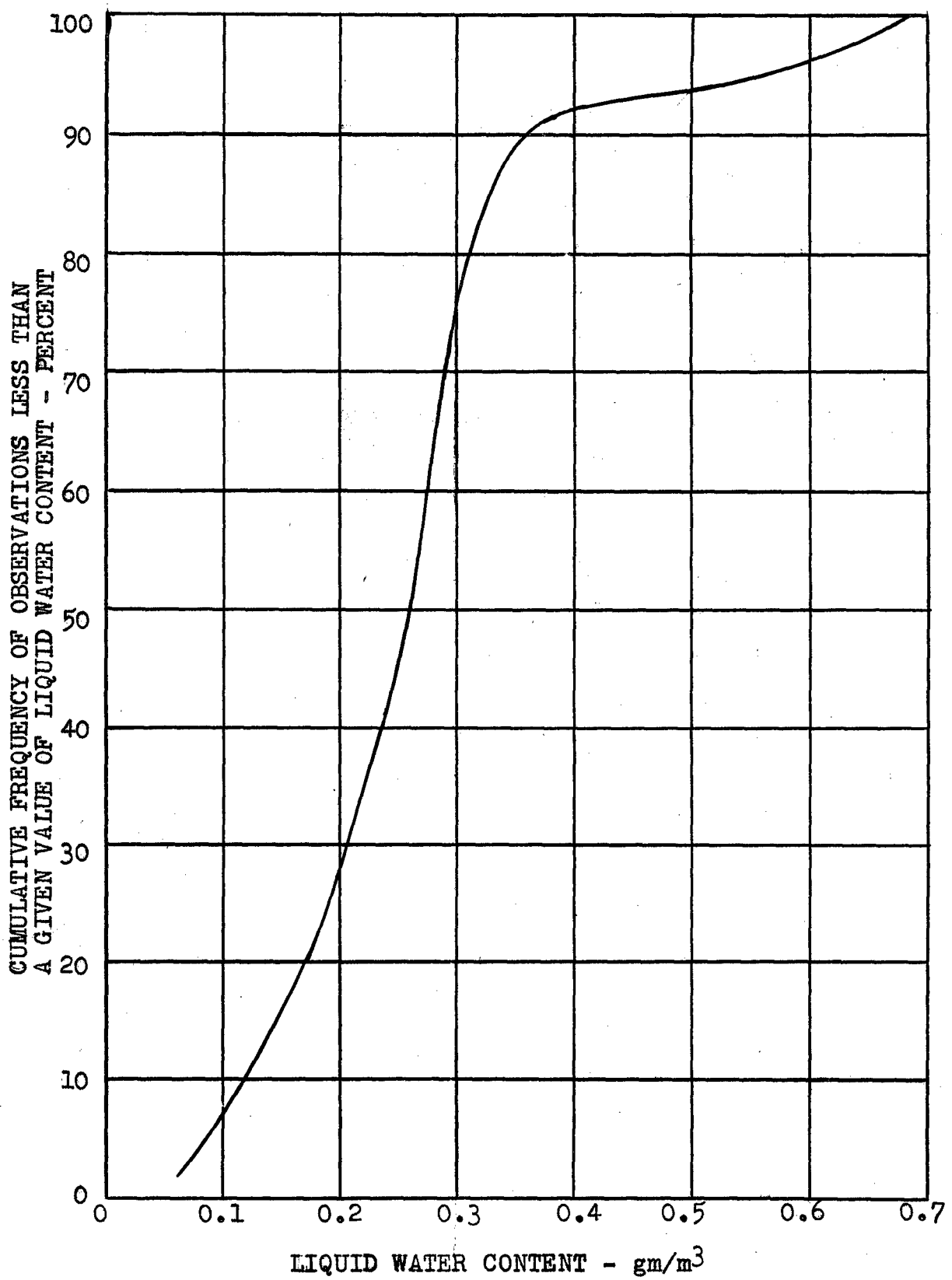

Fig. 1 Cumulative frequency curve of 48 multi-cylinder observations of liquid water content in super-cooled clouds.

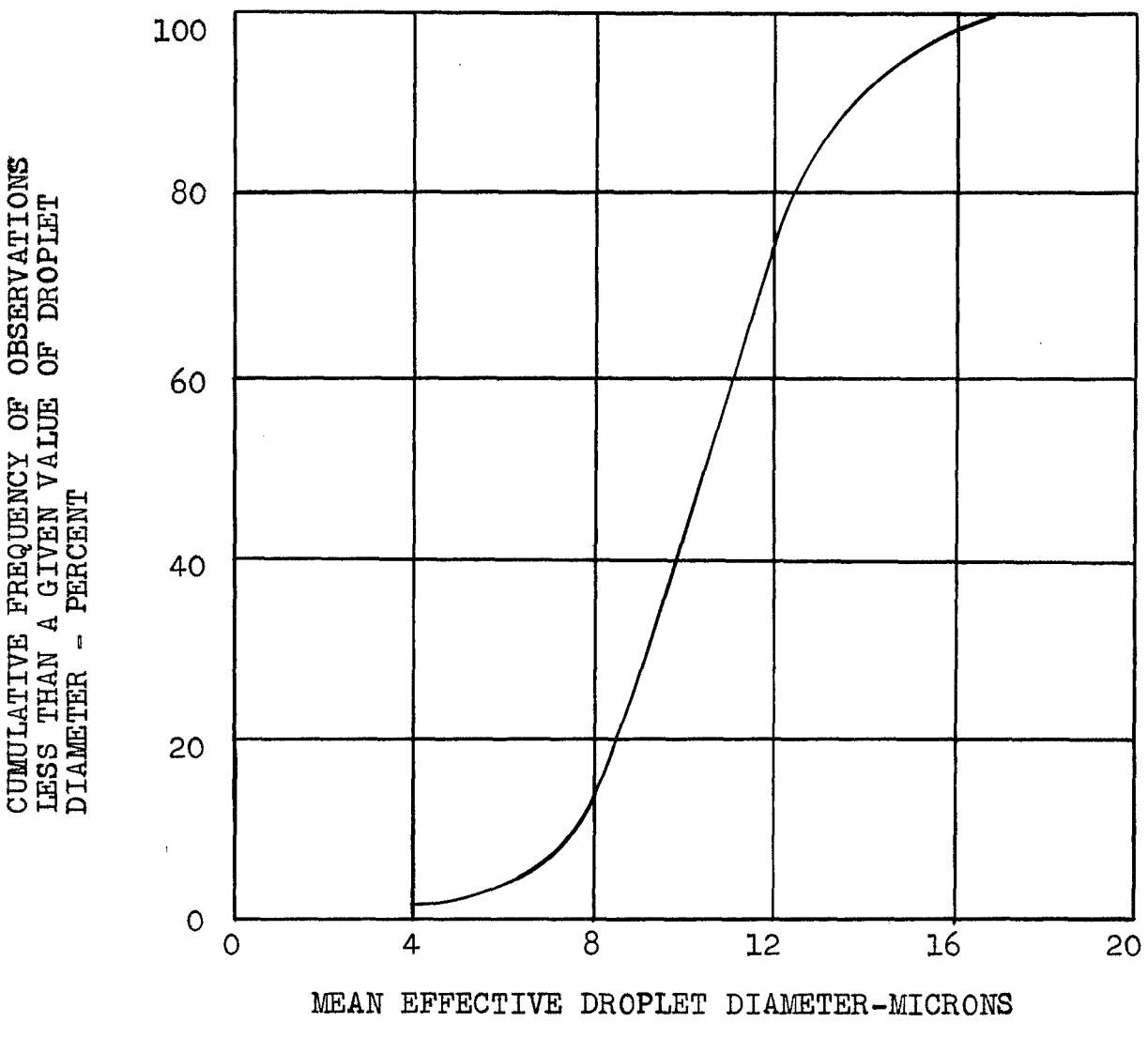

Fig. 2 Cumulative frequency curve of 48 multi-cylinder observations of the mean effective droplet diameter in supercooled clouds.

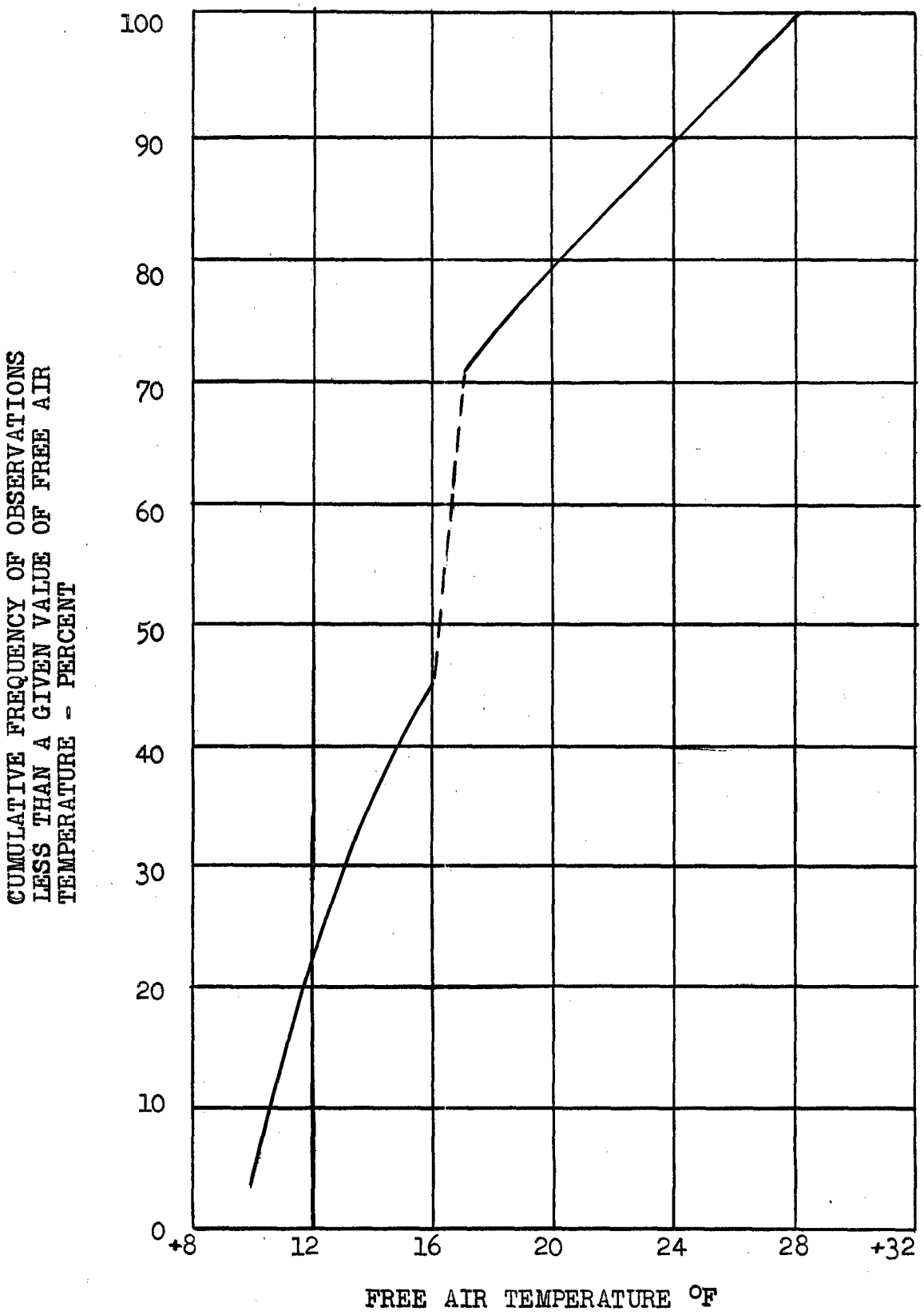

Fig. 3 Cumulative frequency curve of the free air temperature measured during flights in supercooled clouds.

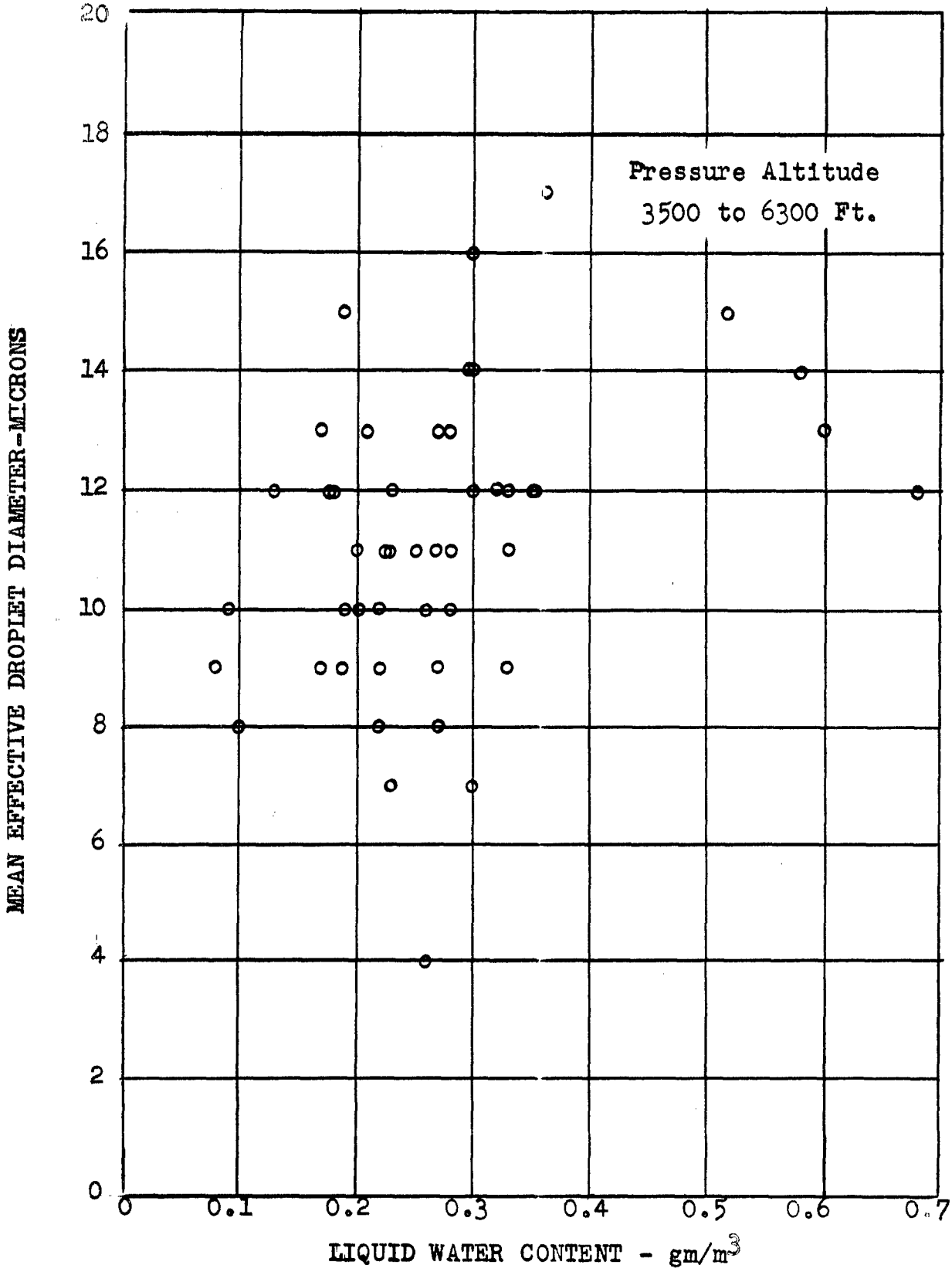

Fig. 4 Variations of liquid water content and mean effective droplet diameter for 48 multi-cylinder exposures.

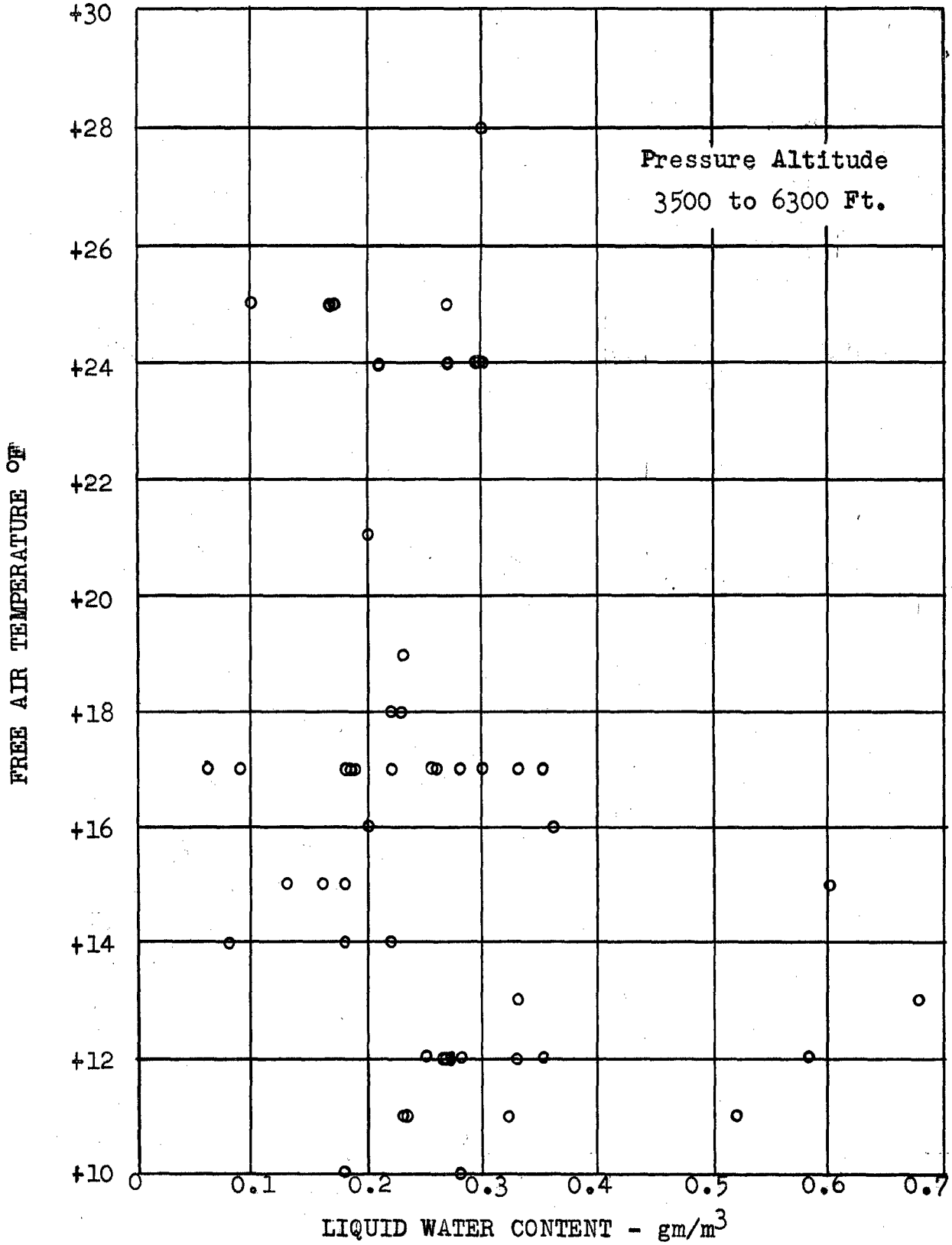

Fig. 5 Variation in liquid water content and free air temperature measured during multi-cylinder exposures.

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