CANADA

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Technical Memoranda

DEVELOPMENT OF A MOVING FOIL HAIL RECORDER

by

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CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH
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DEVELOPMENT OF A MOVING ALUMINUM FOIL HAIL RECORDER

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ABSTRACT

A moving aluminum foil hail recorder was designed and developed. During the summer of 1968 hailfall data were obtained from four hailstorms. The data from the storm of July 28 were analyzed. The analysis shows that the hail fell in small bursts with the largest hailstones falling in the second half of the storm.

MISE AU POINT D'UN ENREGISTREUR DE GRÊLE À FEUILLE D'ALUMINIUM MOBILE

par

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RÉSUMÉ

L'auteur a conçu et mis au point un enregistreur de grêle à feuille d'aluminium mobile. Durant l'été de 1968, il a obtenu des données sur quatre tempêtes de grêle. Les données de la tempête du 28 juillet ont été analysées, et l'analyse indique que la grêle est tombée en courtes rafales et que les grêlons les plus gros sont tombés pendant la seconde moitié de la tempête.

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(Manuscript received October 22, 1968)

1. Introduction

In the summer of 1968 one of the projects undertaken by the Alberta Hail Project was the development of a hail recorder. It was desired that the hail parameters measured by the recorder would supplement the parameters obtained by hail surveys. Analysis of the hail surveys conducted by the Alberta Hail Project over the last decade (1) shows among other statistics that the probability of a hail day, i.e. a day on which at least one hail report is received, is largest in June (68%); that the mean hail onset time is between 1500 and 1700 MST; that the mean hailfall duration is ten minutes and that during the 1957 - 1966 period pea size hail fell most frequently (38.7%). The hail recorder, on the other hand, would provide statistics about the hail size distribution within the hailfall, the total number of stones, and the total mass of ice incident upon a unit area per unit time.

2. A Survey of the Existing Hail Recorders

With the increasing interest in the microstructure of hailfall during the recent years, a number of recording hail gauges have been under development and some are being evaluated at the present time. In the summer of 1959 Schleusener and Jennings (2) developed the aluminum foil hail indicators which were used in the evaluation of a hail-suppression project in northeastern Colorado. McNeil and Houston (3) in 1966 made a survey of methods of remote detection of hail and found a second-order momentum sensor a promising proposition for further development. In 1968 Fremstad (4) completed a transducer for the measuring of hailstone momentum. This instrument is currently being evaluated. Also in 1968 a mechanical recording hail gauge was developed by Mueller and Changnon (5). This hail gauge is now being field tested in Illinois.

3. The Design Criteria

The findings obtained from hail surveys, conducted by the Alberta Hail Project, gave valuable information for design criteria. It was observed that many Alberta findings were similar to those used by Mueller and Changnon in Illinois. The following design criteria, based on Alberta observations, were adopted before the development of the hail recorder began:

1. The hail recorder should cost less than $500 when mass produced,
2. the recorder should be rugged and suited for mobile operations,
3. the recorder should record against time the size or weight of individual hailstones,
4. stone sizes ranging from 4 mm to 9 cm in diameter should be measured,
5. the time resolution between successive stone falls should be one second or less,
6. the time of beginning and ending of hail should be recorded to the nearest few seconds,
7. the recorder should be able to record continuously for 45 minutes or more,
8. it should be possible to record hail data for a number of short separate storms without having to service the recorder,
9. the recorder should be easily installed and serviced and
10. no external source of 110V power should be required.

4. Experimental Survey

It was desired to develop a hail recorder which would satisfy all of the design criteria based on the Alberta Hail Project findings.

Experiments began by testing whether a relative inexpensive acoustical device could be developed for the measurement of hailstone parameters. Apparatus consisted of a small Philips tape recorder, a SPEEDOMAX COMPACT AZAR strip chart recorder, a stand, sensing plates of various materials (steel, brass, aluminum, tin, plexi-glass), and several hailstones.

Different size hailstones were dropped onto the sensing plate. The sound produced by the impact was recorded onto magnetic tape. Sensing plates of different materials were used to determine the effect of sensing material on the pulse amplitude. Hailstones were dropped onto various locations on the sensing plate to determine the error due to edge effects. The same hailstone was dropped several times to see if the amplitude stayed constant for a given stone mass. The height of drop was also varied. The tape recording was displayed on the strip chart recorder after each trial.

The strip chart recordings showed a general increase in amplitude with increasing stone mass; however, there were considerable amplitude fluctuations. It was found that amplitude fluctuations for a constant mass were least when a plexi-glass sensing plate was used. The edge effects became important when the hailstones struck the plate at a distance greater than 50% from the centre. The only effect of the variation of height from which stones fell was that as the height was increased the amplitude was also increased.

To decrease the amplitude fluctuations, two plates with a dielectric between them were used. As the stones fell onto the upper plate, changes in capacitance were recorded. The changes were relatively small and it appeared that signal amplification was required to achieve meaningful results. The capacitance experiments were terminated in favor of mounting a strain gauge onto a sensing plate and recording the deflections caused by the falling hailstones. A SANBORN MODEL 321 amplifier recorder was used for recording. The results, using the strain gauge, were very satisfactory and would warrant further development, although the cost of the recorder is very high.

Experiments continued with testing of light attenuation to determine if it could be used to measure the hail size. The apparatus consisted of two lenses, a photovoltaic cell and a light source.

The two lenses were placed four inches apart. The light source was mounted at the focal point of the first lens and the photovoltaic cell was placed at the focal point of the second lens. Hailstones were dropped between the lenses and variations in photovoltaic cell output were recorded on a voltmeter. It was observed that the output signal varied with the hailstone size in the anticipated fashion; however, due to lack of proper optical equipment further experiments were not possible.

To remove the need for a pulse recorder, experiments were carried out to determine the relationship between hailstone diameter, or weight, and the dent diameter caused when a hailstone fell onto aluminum foil. Apparatus consisted of different types of styrofoam pads[1], aluminum foil[2] (regular and extra heavy), and several hailstones. First the diameter and weight of each hailstone were obtained. The measurements were performed in a freezer to prevent the hailstones from melting. Then several trials were made dropping the hailstones on to aluminum foil covered styrofoam pads. The diameters of dents were then measured. Different types of styrofoam and aluminum foil were used to determine which combination gives best impressions. The height of fall was varied. The angle of the styrofoam pad was also varied to simulate various angles of incidence. The same stone was dropped several times to determine if the dent diameter remained constant for a given stone mass. Graphs of hailstone weight and diameter versus dent diameter were plotted after each trial. It was observed from the graphs the relationship between hailstone weight

1 Regular styrofoam with density 0.228 g/cm^3 and pressed styrofoam with density 0.259 gm/cm^3 were used.

2 ALCAN aluminum foil was used. The alloy Alcan is about 99.3% aluminum and has a density of 0.098 lbs./cubic inch. The gauges for regular and extra heavy foil are 0.0007" and 0.001" respectively. This foil is produced with slight temper and the mechanical properties for 0.0007" are: ultimate tensile strength 12.5 ksi, yield strength 10.5 ksi, elongation 4%. The 0.001" has an ultimate tensile strength of 11.5 ksi, yield strength 7.0 ksi and elongation 5%.

and dent diameter was better than between hailstone diameter and dent diameter. One of the reasons for this discrepancy was the fact that hailstones were not perfect spheres which made exact diameter measurements difficult. It was also found that the correlation between hailstone weight and the dent diameter was best:

1. when pressed styrofoam, covered with extra heavy foil, was used,

2. when the height of fall was greater than 30 cm, and

3. when the angle of incidence was zero degrees. It was noted that when the same stone was dropped several times the differences between the shape and size of dents were very slight. It was estimated that the error in determining the hailstone weights from dent diameters was within 20%. Figure 1 shows graphs of hailstone weight and size plotted against dent diameter.

The graphs in Figure 1 were obtained using hard hailstones. Soft, spongy hailstones which are sometimes found in nature were not available, however, it is realized that additional calibration problems would appear if such hailstones were used. Several of the hailstones used in calibration were melted and their density was found to be 0.9 gm/cm^3.

5. Design and Development of the Moving Aluminum Foil Hail Recorder

Experimental survey suggested that a hail recorder based on electronic measurements would require a fairly expensive pulse recording equipment. It became evident that a recorder based on mechanical recording would be far less expensive than one in which recording was done electronically. After some deliberation aluminum foil recording was accepted as a reasonable solution.

The moving aluminum foil hail recorder was designed to measure and record, against time, the size and weight of individual falling hailstones. Also it recorded the time of occurrence and duration of hailfall. The recording of the hailstone sizes was done by letting the hailstones fall perpendicularly on to a moving aluminum foil from a fixed height. From calibration curves the weight and size of each hailstone was determined as a function of dent diameter.

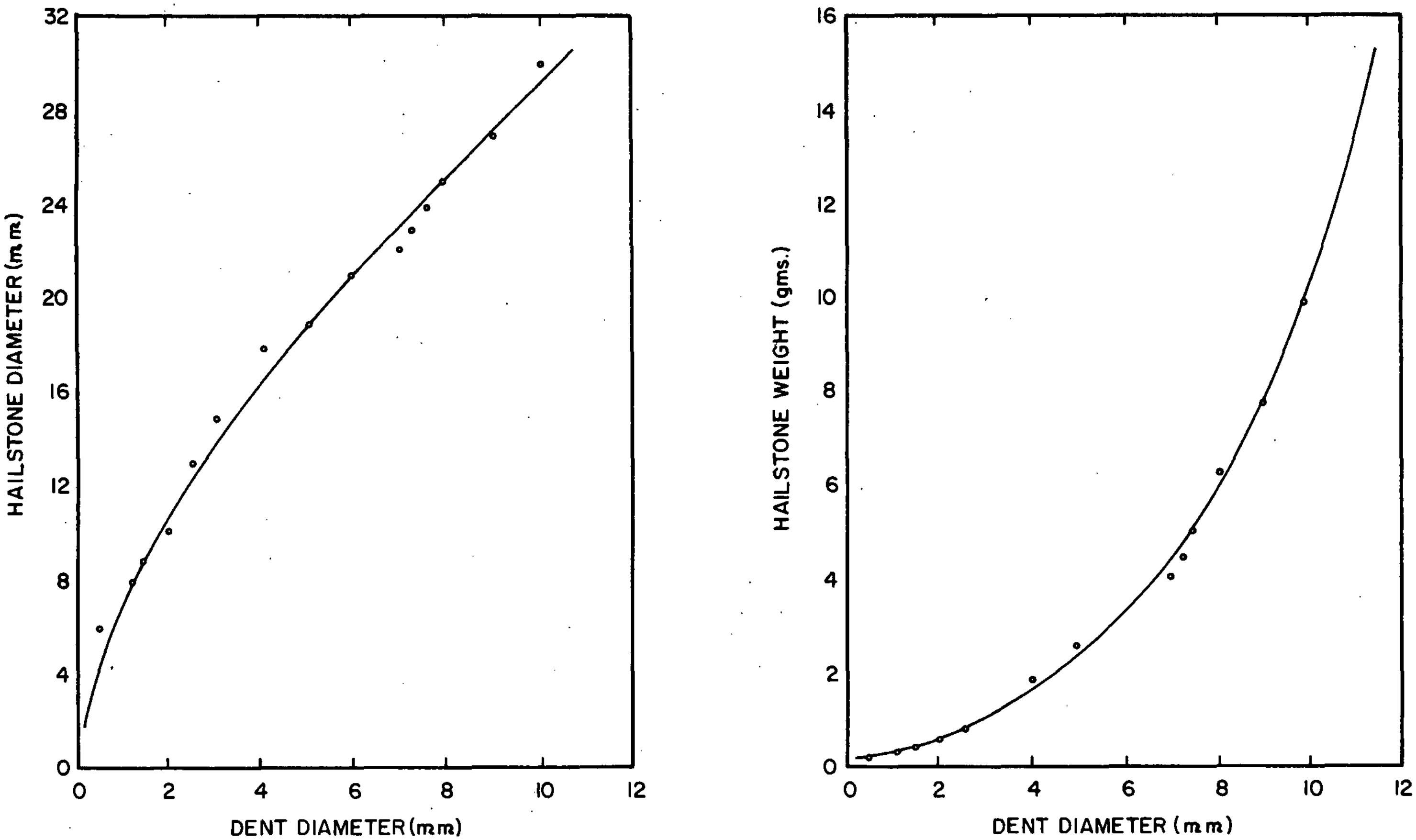


Figure 1
Graphs Showing the Relationship Between Hailstone Diameter and Dent Diameter and Between Hailstone Weight and Dent Diameter

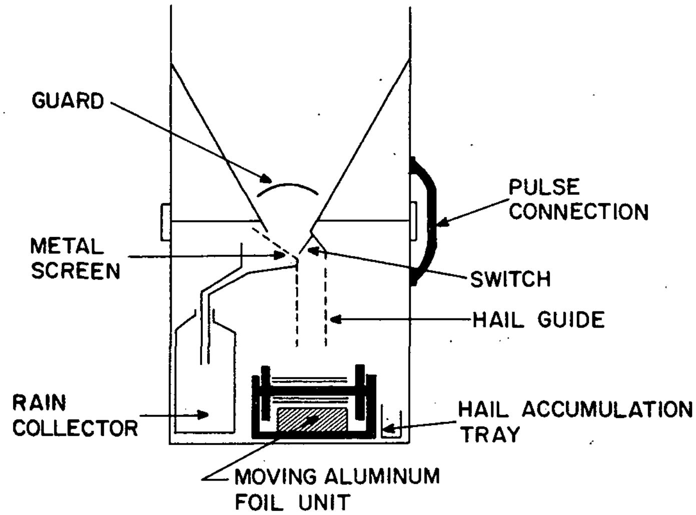
The time of occurrence of hail, its duration and the time intervals between successive hailstones were recorded on Rustrak pressure sensitive paper. The recording consisted of a number of black lines indicating the number of hailstones and the time of each stonefall.

The hail recording was started by the first hailstone falling into the 18-inch square collector aperture. The collector was padded to prevent the hailstones from breaking. After the hailstone fell into the collector it rolled down a short inclined wire mesh trough rain-hail separator, triggered a switch, and then fell on to the aluminum foil. The switch, which consisted of a very light plastic gate, produced a pulse which closed a microswitch and thus started the 6V battery operated motor which drove the aluminum foil. The pulse was recorded on the Rustrak. Each successive hailstone produced a further pulse which was recorded by the Rustrak. After the hailfall stopped, the motor remained running for approximately three minutes and then was shut off by an electronic timer. This prevented the waste of foil. The Rustrak ran continuously while the hail recorder was in operation.

The power supply for the hail recorder consisted of two 6V batteries. One of the batteries ran the Rustrak recorder; the other, the aluminum foil motor. The Rustrak recorder ran at 30 inches per hour, while the aluminum foil moved at 30 cm per minute. Side and plan views of the recorder are shown schematically in Figure 2 and the electronic circuit diagram is shown in Figure 3.

6. Data Acquisition

The aluminum foil hail recorder was completed late in June 1968 and was operational during July and August. The recorder became part of the mobile sampling unit, a half ton instrumented panel truck. This truck was directed into storms by radio communication with base radar. During the period of operation the hail recorder was under a hailstorm on July 15, 17, 25, and 28. The recorder was observed during each hailfall and it operated in a very satisfactory manner. Figure 4 shows the hail recorder in operation during the storm of July 28, about 15 miles west of Rocky Mountain House (land location is SE-19-40-9-5).



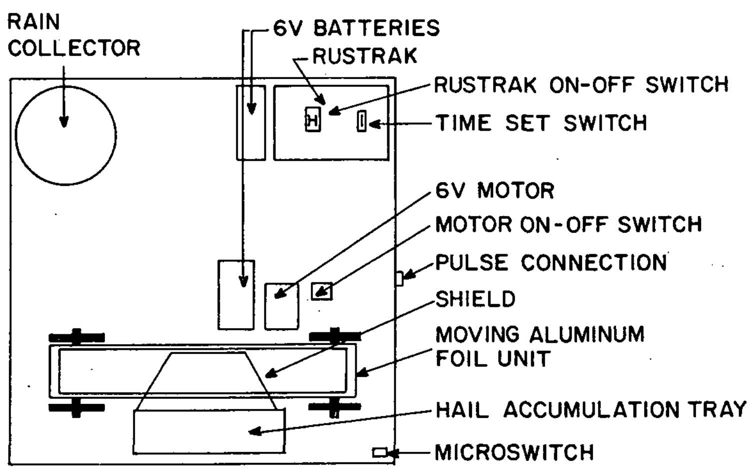
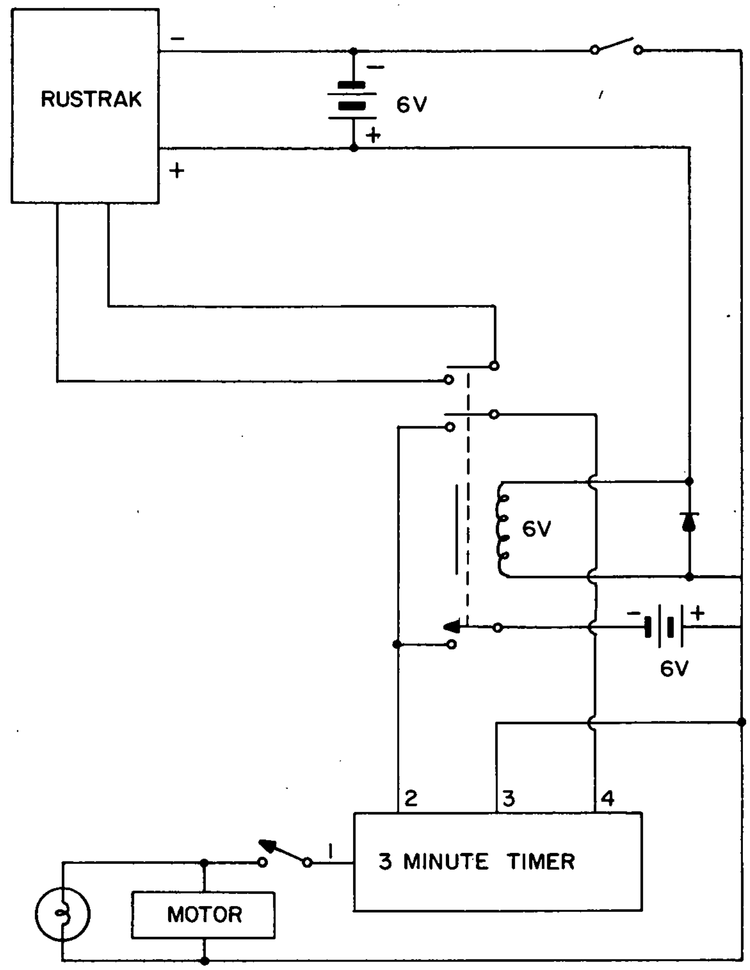


Figure 2
Side and Plan View of the Hail Recorder



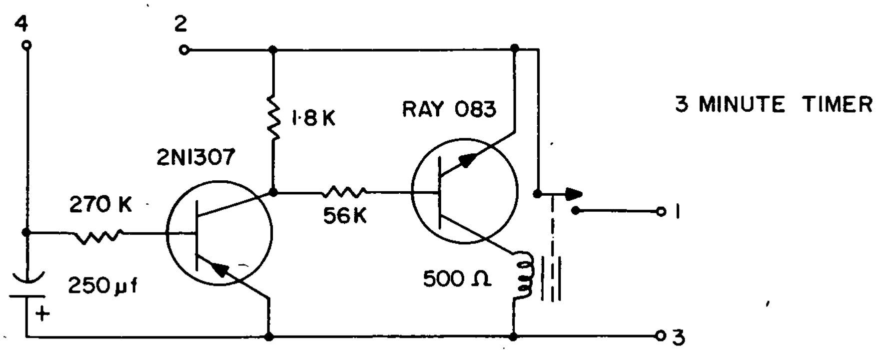


Figure 3
Electronic Circuit Diagram for the Hail Recorder

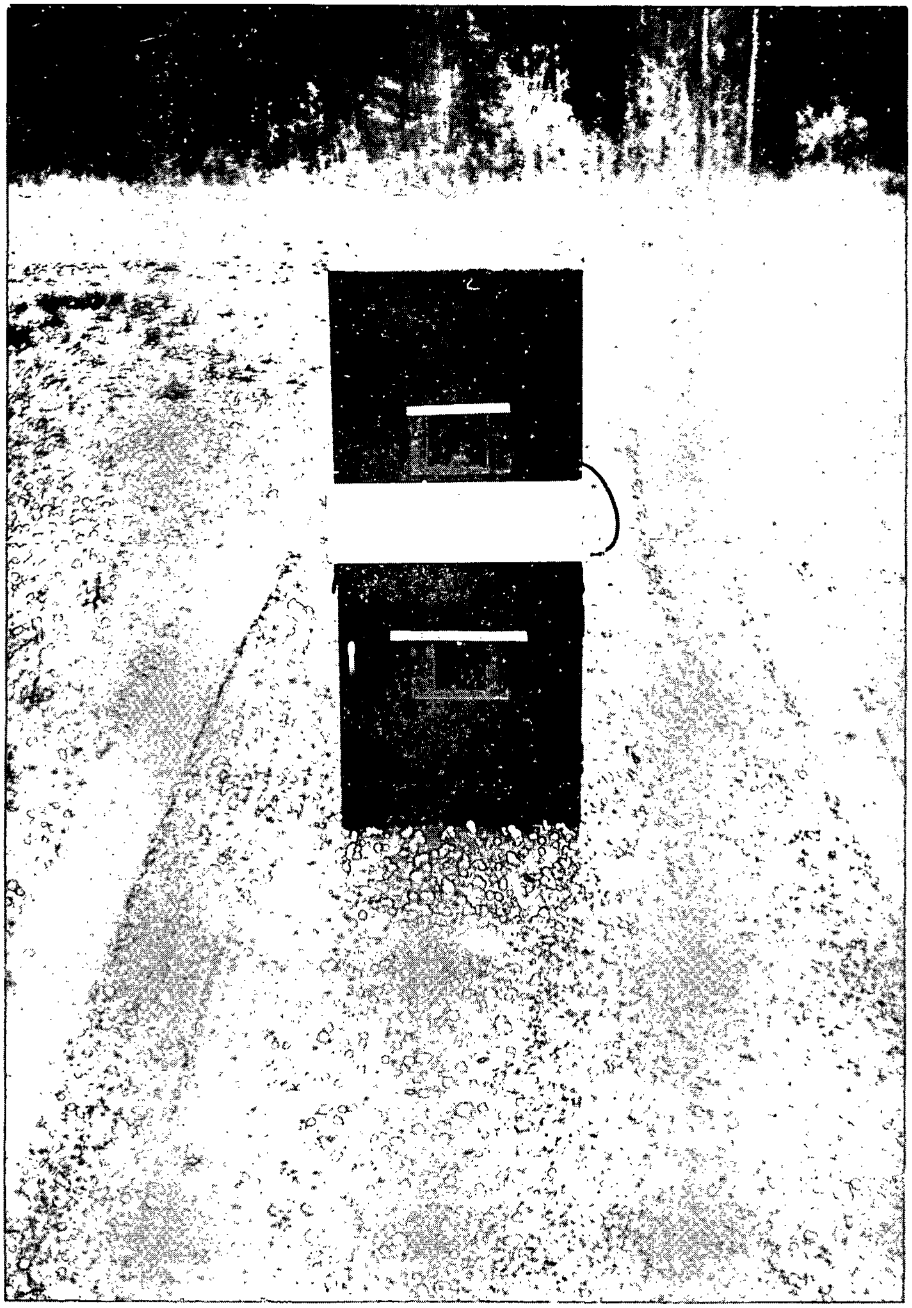


Figure 4
Hail Recorder inOperation

7. Data Analysis and Conclusions

The hailfall records obtained from the first three storms are short and show only shot and pea size hail. However, the storm of July 28 produced larger hailstones. The hailfall data for this storm are given in the appendix. The time required to process the hailfall record for the storm on July 28 was approximately one hour. The data show that 70 hailstones fell into the recorder between 1907 and 1926 MST. The stones ranged from 0.1 to 2.4 grams in weight or from 6 to 17 mm in diameter. The total weight of ice which fell into the hail recorder during the storm was calculated to be 17.8 gms/ft^2. A graph of hail stone weight versus time was plotted, (Figure 5). It is observed from the graph that there was a small burst of pea-size hail between 1907:00 and 1907:30 with the main hailfall starting at 1918:04. During the main hailfall 31 stones (50%) of the sample fell during the first 375 seconds and 32 stones fell during the last 97 seconds. The largest captured hailstones fell during the second half of the hailfall. It is also observed from the graph that the stones fell in little bursts lasting between 4 to 20 seconds. The surface wind during the hailfall period was almost calm and the rainfall was very light. An aluminum foil covered hail indicator, one square foot in area, which was located about ten feet from the hail recorder showed 33 hailstone dents of pea and grape size.

A histogram, for the July 28 hail data, was also constructed, (Figure 6). The histogram shows that frequency is largest for hailstones in the class interval 0 - 0.39 grams. Since the maximum frequency occurs at one end and then decreases rapidly the histogram could be approximated with a reverse J shaped smoothed frequency polygon. It is realized however, that further investigations will be necessary to determine the validity of the above approximation.

To determine the usefulness of the aluminum foil hail recorder further field evaluation will be necessary. It is hoped that with minor modifications the recorder will be used again during the summer of 1969 to collect hail data.

8. Acknowledgement

The initial suggestions concerning the development of a hail recorder were made by Dr. P. W. Summers, field co-ordinator,

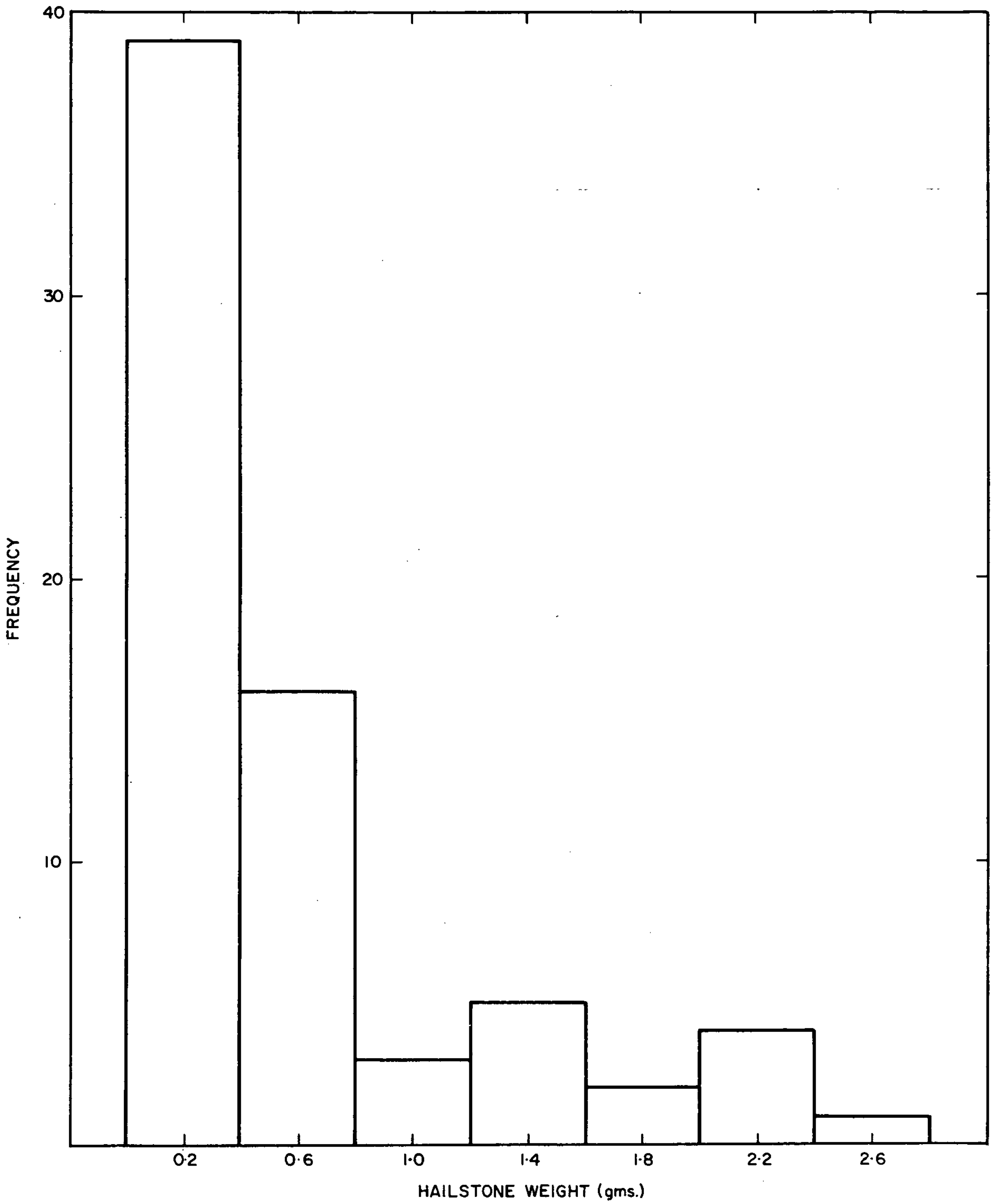


Figure 5
Hail Sequence for Storm of July 28, 1968
Location SE-19-40-9-5

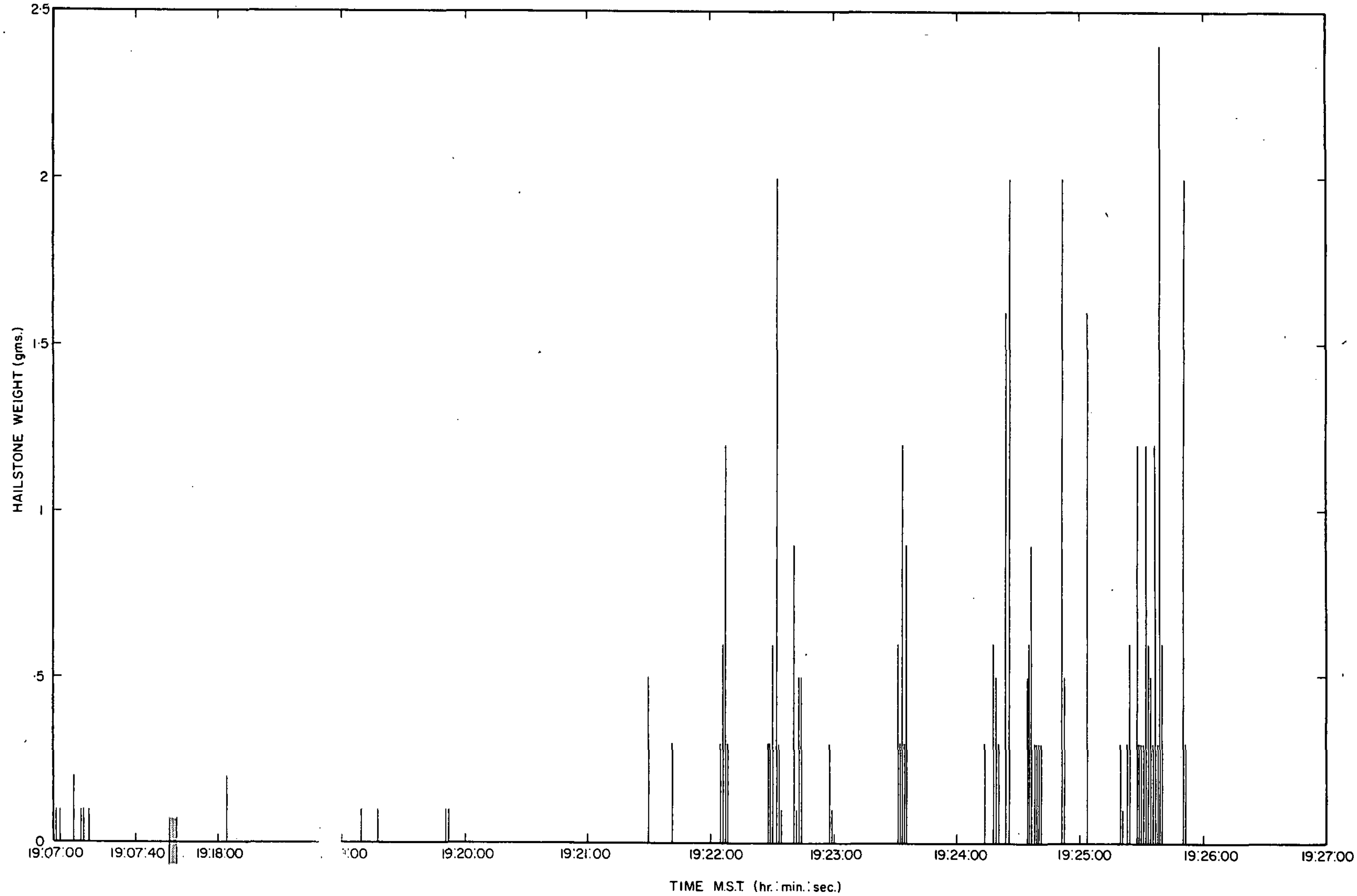


Figure 6
Histogram for the July 28, 1968
Hail Data

Alberta Hail Project. Project technicians Russ Schnell and Fred McDougall and summer assistants Paul Hickson and Jim Mallas assisted in several phases of the work. The project was carried out during educational leave from the Meteorological Branch, Department of Transport.

APPROVED,

D. P. McIntyre

for J. R. H. Noble,
Director,
Meteorological Branch.

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APPENDIX

Hail Recorder Data for Storm of July 28, 1968
Location SE-19-40-9-5

No	Time (MST)	Dent Diam	Hailstone Diam(mm)	Hailstone Wt. (grms)
1	19:07:02	.5	6.0	.1
2	07:03	.5	6.0	.1
3	07:10	.8	7.0	.2
4	07:14	.5	6.0	.1
5	07:15	.5	6.0	.1
6	07:18	.5	6.0	.1
7	18:04	.8	7.0	.2
8	19:10	.5	6.0	.1
9	19:18	.5	6.0	.1
10	19:50	.5	6.0	.1
11	19:52	.5	6.0	.1
12	21:30	1.5	9.5	.5
13	21:42	1.0	7.5	.3
14	22:05	1.0	7.5	.3
15	22:06	2.0	11.0	.6
16	22:07	3.0	14.5	1.2
17	22:08	1.0	7.5	.3
18	22:28	1.0	7.5	.3
19	22:29	1.0	7.9	.3
20	22:30	2.0	11.0	.6
21	22:32	4.0	17.0	2.0
22	22:33	1.0	7.5	.3
23	22:34	.5	6.0	.1
24	22:41	2.5	13.0	.9
25	22:42	1.0	6.0	.3
26	22:43	1.5	9.5	.5
27	22:44	1.5	9.5	.5
28	22:58	1.0	7.5	.3
29	22:59	.5	6.0	.1
30	23:31	2.0	11.0	.6
31	23:32	1.0	7.5	.3
32	23:32	.5	6.0	.1
33	23:33	3.0	14.5	1.2
34	23:34	1.0	7.5	.3
35	23:35	2.5	13.0	.9
36	24:13	1.0	7.5	.3
37	24:18	2.0	11.0	.6

No	Time (MST)	Dent Diam	Hailstone Diam(mm)	Hailstone Wt. (grms)
38	19:24:19	1.5	9.5	.5
39	24:20	1.0	7.5	.3
40	24:24	3.5	16.0	1.6
41	24:26	4.0	17.0	2.0
42	24:34	1.5	9.5	.5
43	24:35	2.0	11.0	.5
44	24:36	2.5	13.0	.9
45	24:38	1.0	7.5	.3
46	24:39	1.0	7.5	.3
47	24:40	1.0	7.5	.3
48	24:41	1.0	7.5	.3
49	24:51	4.0	17.0	2.0
50	24:52	1.5	9.5	.5
51	25:03	3.5	16.0	1.6
52	25:20	1.0	7.5	.3
53	25:21	.5	6.0	.1
54	25:23	1.0	7.5	.3
55	25:24	1.0	11.0	.6
56	25:28	3.0	14.5	1.2
57	25:29	1.0	7.5	.3
58	25:30	1.0	7.5	.3
59	25:31	1.0	7.5	.3
60	25:32	3.0	14.5	1.2
61	25:33	2.0	11.0	.6
62	25:33	2.0	11.5	.6
63	25:34	1.5	9.5	.5
64	25:35	1.0	7.5	.3
65	25:36	3.0	14.5	1.2
66	25:37	1.0	7.5	.3
67	25:38	4.5	18.0	2.4
68	25:39	2.0	11.0	.6
69	25:50	4.0	17.0	2.0
70	25:51	1.0	7.5	.3

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