THE RELATIONSHIP BETWEEN SNOWFALL DENSITY AND METEOROLOGICAL CONDITIONS

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During the winters of 1960-1961 and 1962-1963 snowfall density measurements were made in downtown Montreal. Concurrent observations of snow crystal types were also made to test the theory that the snowfall density is a function of the predominant crystal type making up the snowfall.

The observations were carried out in central downtown Montreal during the winters of 1960-61 and 1961-62. The snow depth was measured on a roof top, approximately 30 feet above street level. Depth was measured by a series of 25 ruler measurements on a standard snow board 4 feet square.

The weight of the snow corresponding to the measured depth (i.e., the water equivalent of the snowfall) was recorded by a Bendix-Friez recording snow gauge placed alongside the snowboard. From these two measurements, the water equivalent and the depth, the density is calculated at once as the ratio of the two.

The snow crystals falling during the storm were caught periodically in a portable cold box, 12 inches square and 5 inches deep. This box was kept in a deep freeze unit at -20°C; when an observation was wanted it was carried outside. The crystals caught were then observed indoors at leisure under the microscope.

Figure I shows the frequency distribution of snowfall and densities during the two winters of observation. The most frequent density is 8.5% with a second peak about 14% density. This same type frequency distribution was found by Wilson at Burlington, Vermont, with a much larger sample size so that the reality of the two peaks appears established. It is felt that the second peak is a result of the action of riming in causing large density increases on the unrimed frequency distribution.

The results of the crystal type/density determinations are shown in Table I. It can be seen that there is a good general relationship between snowfall density and crystal type; dendrites occur predominantly in snowfalls of lightest density followed by needles, plates, irregular assemblages; while snowfalls of density greater than 10% are composed entirely of rimed crystals. It may be noted that the major snowfalls at Montreal were made up of irregular crystal assemblages. Only one snowfall occurred in the 10% to 12-1/2% range.

Table I - Density/Snow Crystal Form Determinations
For Winter Seasons 1960-61 and 1961-62

Snowfall Density (grams/cm^3)	Predominant Crystal Types	Snow Depth (Inches)	Total Depth Within Density Range	Percentage of Total Sample (61.4")
0-0.050				
0.030	Dendrites	1.5		
0.044	Dendrites-Irregular Crystals	1.7		
0.050	Dendrites	3.0	7.6	12.4
0.050	Dendrites	1.0		
0.050	Dendrites	0.4		
0.051-0.075				
0.060	Needles	1.0		
0.063	Needles Dendrites	4.6		
0.067	Spatial Dendrites	1.5		
0.068	Irregular Assemblages of Columns & Plates Rimed Plates Rimed Dendrites	3.7	14.8	24.1
0.075	Irregular Assemblages of Columns and Plates	2.0		
0.075	Rimed Dendrites Needles Columns	2.0		
0.076-0.100				
0.080	Dendrites	3.5		
0.087	Plates	2.9		
0.088	Spatial Dendrites	2.5		
0.090	Irregular Assemblages of Dendrites	2.1		
0.090	Needles Rimed Dendrites	2.0	30.9	50.3
0.093	Rimed Dendrites Rimed Needles	3.2		
0.098	Columns & Plates			
0.098	Spatial Dendrites	5.7		
0.100	Irregular Assemblages Columns & Plates	4.0		
0.100	Irregular Assemblages of Plates Needles	4.0		
0.100	Dendrites Plates	1.0		

Table I (Cont'd)

Snowfall Density (grams/cm^3)	Predominant Crystal Types	Snow Depth (Inches)	Total Depth Within Density Range	Percentage of Total Sample (61.4")
0.101-0.125				
0.109	Heavily Rimed Dendrites	3.7	3.7	6.0
	Rimed Needles			
0.126				
0.140	Rimed Dendrites	3.0		
	Rimed Plates			
0.143	Rimed Plates	0.8		
0.167	Rimed Plates	0.3	4.4	7.2
	Rimed Dendrites			
0.230	Dendrites	0.3		
	Small Graupel			

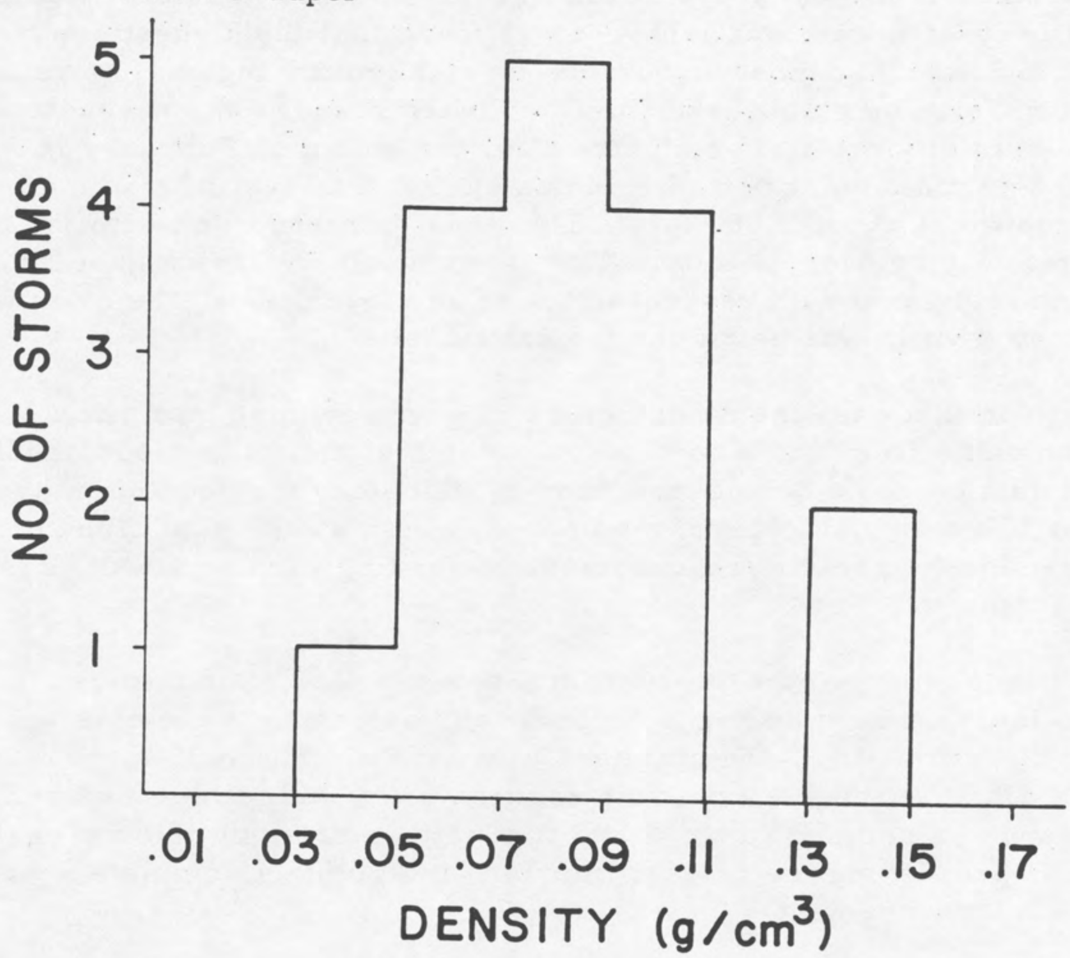

FIGURE I

HISTOGRAM GIVING FREQUENCY OF SNOWFALLS IN VARIOUS DENSITY RANGES

The results look encouraging, however a word of caution is necessary. The samples are all small and excluded from the study were falls of wet melting snow, storms with heavy drifting, etc. Further observations are needed for better determination of the relationships and in particular a future study should include data on crystal aggregation and crystal sizes. The total sample, namely 61.4 inches, amounted to 33% of the total snowfall measured during the two winters. The average density over all storms was 0.085g/cm^3.

The effects of riming (the collection of frozen cloud droplets on the crystals) in causing increased snowfall density is very marked. The increases are greatest with plates and dendrites than with needles. This is probably because more droplets are swept up or collected by a falling plate or dendrite than by a needle because of different cross-sectional areas.

In the course of studying various individual cases it was found that favourable conditions for snow growth often occur in relatively thin layers aloft at the base of frontal inversions rather than in the overrunning warm air above the frontal zone as is usually more readily assumed. In 74% of cases studied where radiosonde data were available, it was found that the highest supersaturations with respect to ice, i.e., most favourable crystal growth regions, were found at the base of the inversion or stable layer aloft. Figure II shows the reconstructed temperature/humidity profile for Montreal for the storm of February 16, 1962. In this storm the vertical pointing radar indicated that the level of maximum snow growth was topped at about 6,000 feet. This level corresponded with the base of a frontal inversion lying over the city. This layer at the inversion base showed the greatest supersaturation with respect to ice of any level, i.e., the most favourable region for snow growth was below the frontal surface.

Although in this case the natural snow crystals seeding into this low-level growth region came from above, it would appear that artificial cloud seeding in this type of situation could be accomplished by releasing the seeding material into the air either above or below the inversion. It would appear that study of the relative merits of the two different methods of seeding such a growth region might be of considerable interest.

It was also found that the snow crystal types falling often changed during a storm and to insure a better sample a continuous automatic snow crystal recorder was developed (Figure III). The unit basically uses a strip of 35 mm clear plastic film which is drawn through a Formvar solution bath, and is then exposed to the falling snow under a sampling port. The film is then dried at below freezing temperatures, preserving the crystal imprints and giving a complete record for later study and measurement.

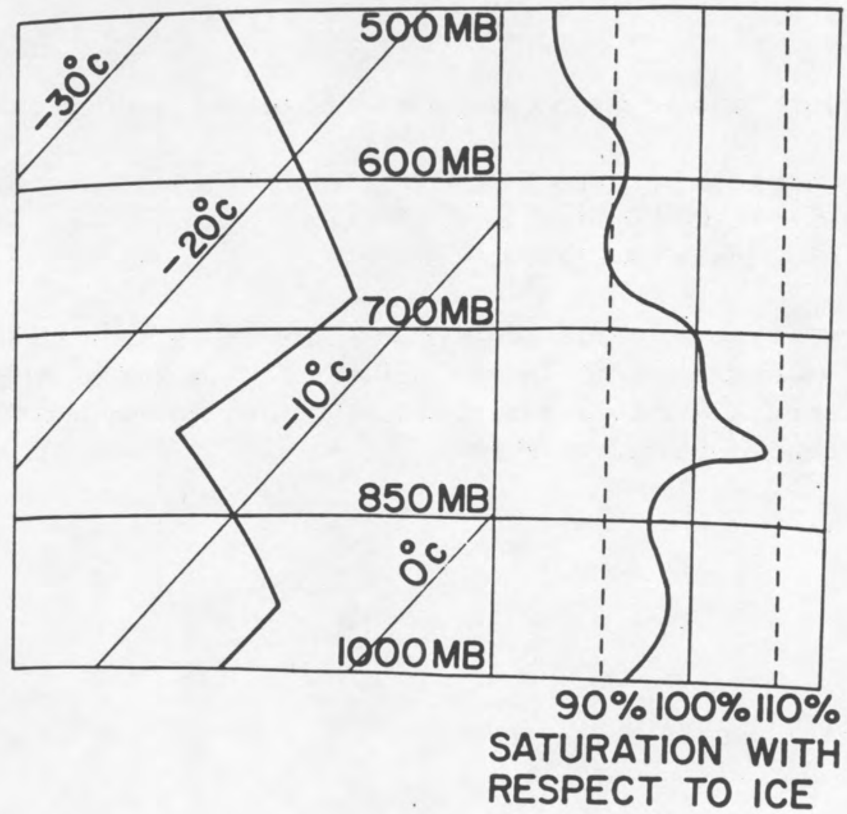

FIGURE II

RECONSTRUCTED SOUNDING FOR MONTREAL 7 p.m. EST, FEBRUARY 16TH, 1962

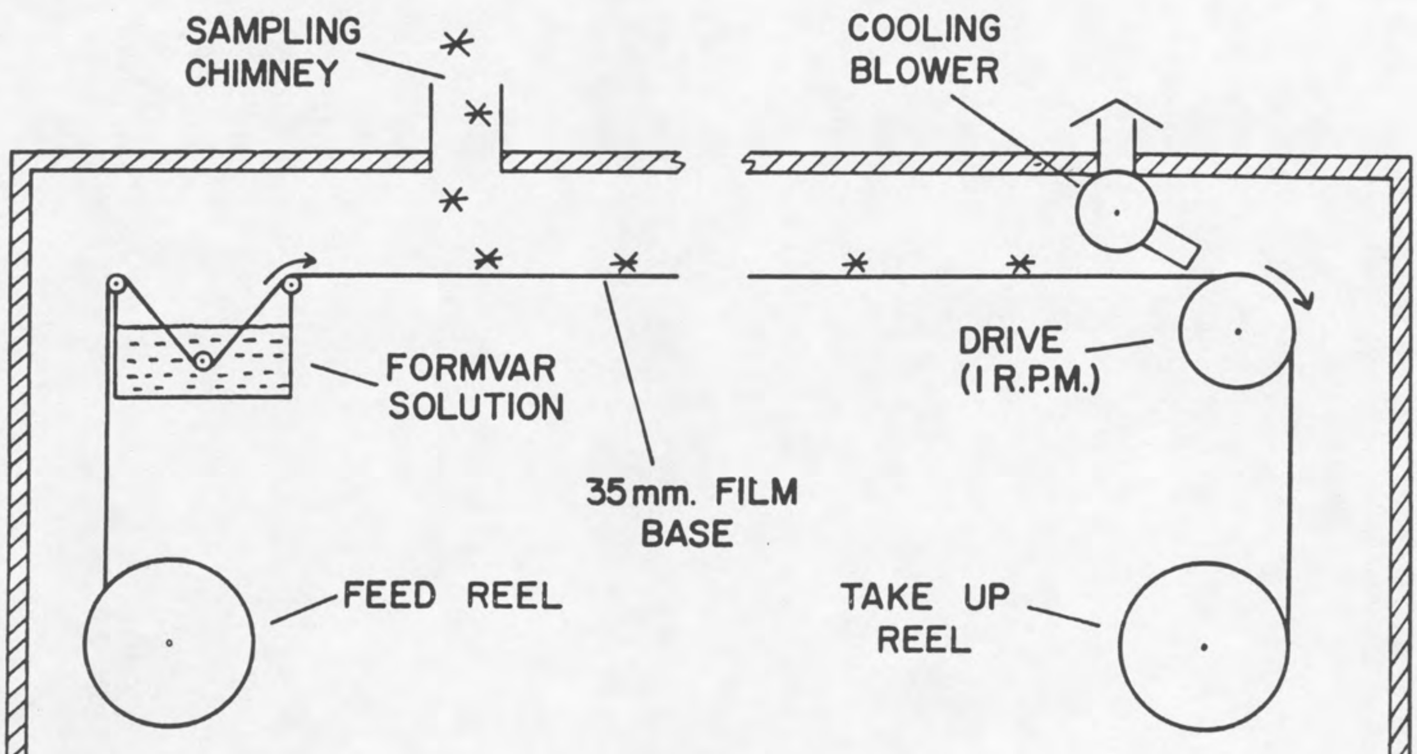

FIGURE III CONTINUOUS AUTOMATIC SNOW CRYSTAL RECORDER

More complete details on the study may be found in the following references:

1) "Relationship between Density of Newly Fallen Snow and Form of Snow Crystals." Bernard A. Power. Nature, Vol. 193, No. 4821, P. 1171, March 24, 1962.

2) "Snow Crystal Forms and Riming Effects as Related to Snowfall Density and General Storm Conditions." Bernard A. Power, P. W. Summers, J. d'Avignon. Journal of the Atmospheric Sciences -- to appear in Spring of 1964.