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The Production of Ice Crystals in a Cloud of Supercooled Water Droplets

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A STUDY OF ICE CRYSTALS and "ice nuclei" has been under way in this Laboratory for some time with the purpose of investigating some of the basic problems related to the icing of aircraft and other cold-weather phenomena.

Recently several experiments have been made with supercooled clouds of water droplets which are interesting and seem worth while to report.

In the experiments to be described a supercooled cloud is formed by introducing moist air into a small, commercial freezing unit having a rectangular well 60 cm. long, 45 cm. wide, and 50 cm. deep. In many instances it is possible to carry out the experiments with the top of the unit uncovered because of the stability of the cold air in the well. This forms a typical temperature inversion with the coldest part of the air at the bottom of the chamber. Under typical laboratory conditions with a room temperature of 27° C., the temperature of the air in the center of the cold chamber is maintained at about −15° C. with the temperature −20° C. at the bottom and −10° C. near the top.

During more than a hundred experiments observed up to the present time, all supercooled clouds formed in the cold chamber have never developed into ice-crystal clouds except under conditions which will be described. Thus, with all of the various types of dust particles normally present in a research laboratory, besides those which would be added by the close proximity of many manufacturing processes, nothing served to initiate the crystallization of the supercooled cloud in the cold chamber. Under normal conditions in the chamber, the cloud persists for periods ranging from 4 to 10 minutes, the life of the cloud depending primarily on the evaporation and diffusion of the water droplets onto the ice-coated walls of the well. In addition to permitting these various types of "commercial" dusts to enter the cold chamber, many ex-

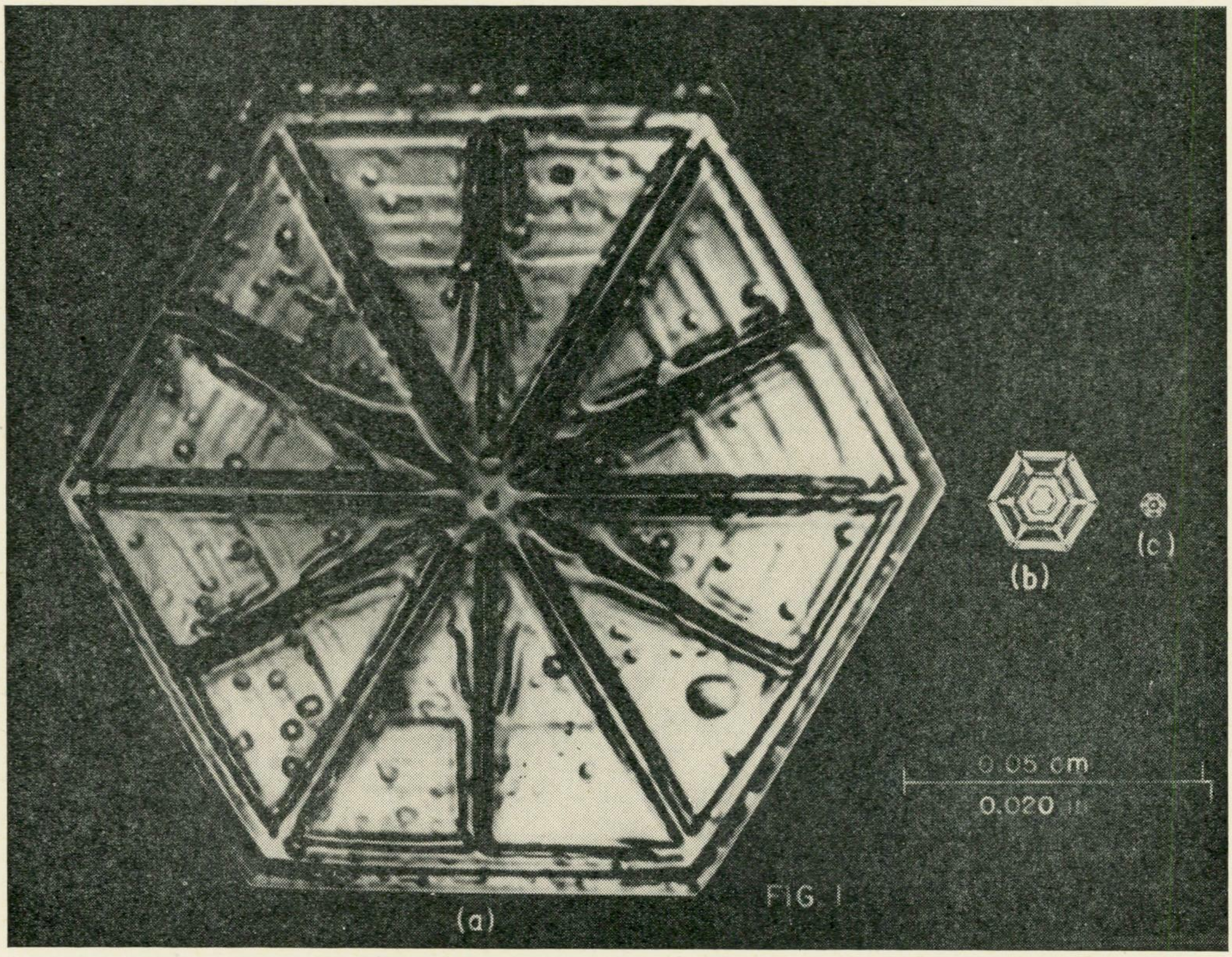

FIG. 1. Photomicrograph of (a) crystal in ordinary snowstorm; (b) type in cirrus cloud; (c) "diamond dust" crystal.

periments were conducted in which samples of various types of fine particles were intentionally added to the supercooled cloud. Carbon, graphite, oil, sulphur, magnesium oxide, volcanic dust, talc, silicates, silica, diatomaceous earth, and many others were introduced as aerosols in an attempt to force the supercooled droplets in the cloud to crystallize.

By using a collimated beam of light from a 32-c.p. lamp in the cloud, the presence of a single ice crystal in the light path is easily observed. Water droplets in the size range of 5–20 μ, such as develop in the experiments described, scatter light mostly in a forward direction. At the same time, a typical water droplet corona can be seen if the lamp housing is removed. An ice crystal, however, due to its crystalline angular faces, scintillates in the light as it tumbles about in the air and reflects light in all directions.

After undertaking many experiments in an attempt to form ice crystals in the supercooled cloud, a piece of solid carbon dioxide (dry ice) was placed in the chamber. Within less than 10 seconds the supercooled cloud was completely converted to one of ice crystals! The introduction of additional water droplets to the cloud only served to make the ice crystals grow, since the vapor pressure of supercooled water is greater than ice. Replicas (*1*) were made of the crystals formed in the cloud, and the microscope showed them to be similar to those found in Nature on cold mornings and known as "diamond dust." The relative size of natural snow crystals is shown in Fig. 1. The smallest of the three crystals in the photomicrograph is a typical crystal of the diamond-dust variety; the largest is a typical hexagonal plate found in an ordinary snowstorm; while the third form occurs in cirrus clouds. Those shown in Fig. 2 are representative of crystals developed in the laboratory cold chamber in

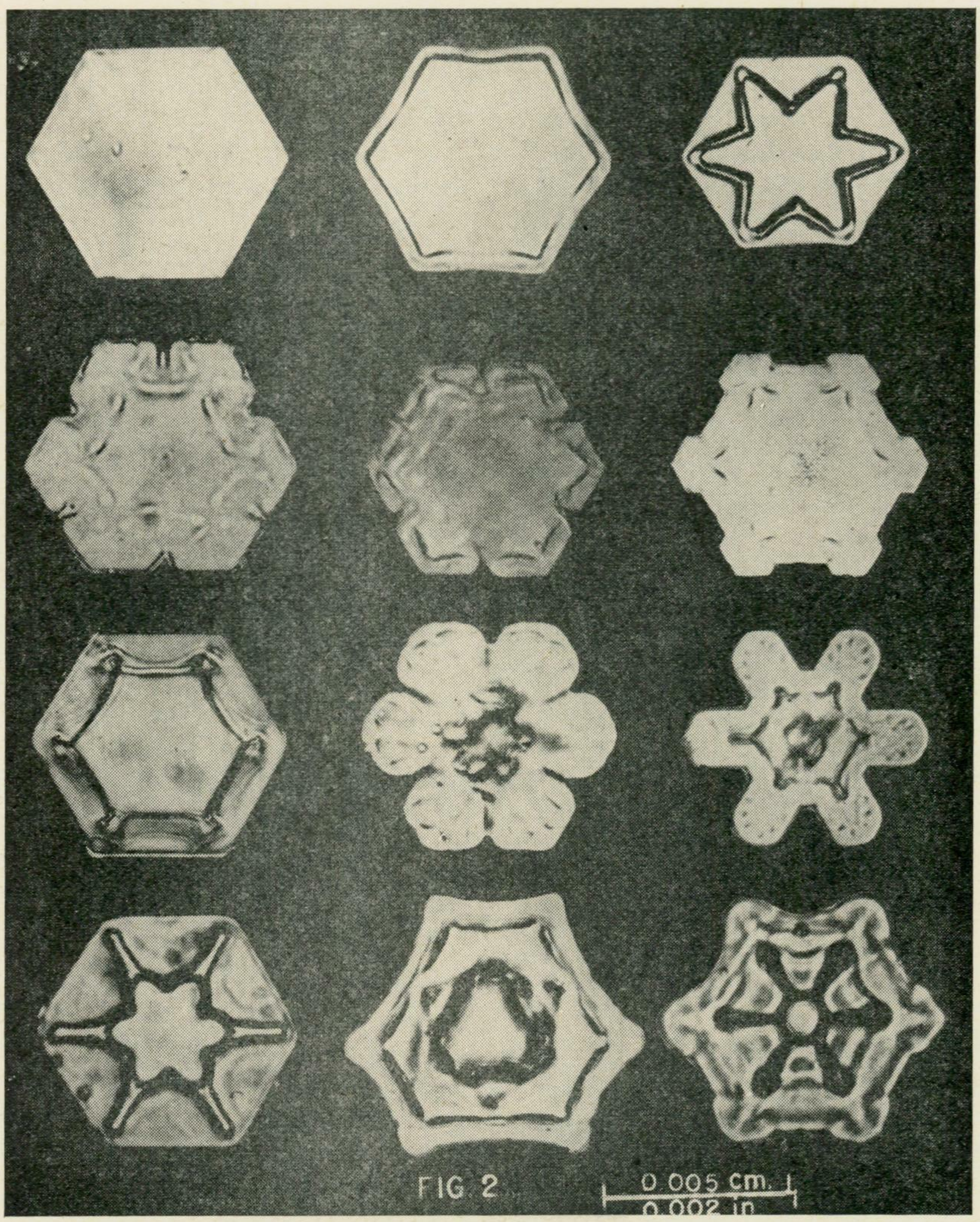

FIG. 2. Crystals formed in laboratory cold chamber.

about 4 minutes after a supercooled cloud was seeded.

Besides using dry ice as a source of ice nuclei, a rod cooled in liquid air and passed rapidly through the supercooled cloud leaves a trail containing great numbers of submicroscopic nuclei which, due to micro-turbulence, spread through the cloud, causing it to dry up as the ice crystals grow. Subsequent experiments show that myriads of ice nuclei form spontaneously if a copper rod having a temperature of $-35°$ C. is placed in a supercooled cloud having a temperature of $-12°$ C. When replicas are made of the nuclei, which stream from the copper rod, they are found to have dimensions of less than 1 μ. Some of these tiny crystals show the trigonal symmetry of crystalline ice and are thin, triangular prisms.

Experiments are under way to investigate various aspects of this spontaneous development of ice crystals in order to determine whether relationships can be established between the laboratory experiments and the natural atmosphere.

It is planned to attempt in the near future a large-scale conversion of supercooled clouds in the atmosphere to ice crystal clouds, by scattering small fragments of dry ice into the cloud from a plane. It is believed that such an operation is practical and economically feasible and that extensive cloud systems can be modified in this way.

Reference

1. Schaefer, Vincent J. *Science,* 1941, **93**, 239; *Nature, Lond.*, 1942, **149**, 81.

October 15, 1946

Dr. Willard L. Valentine
Science
Massachusetts and Nebraska Avenues
Washington 16, D.C.

Dear Dr. Valentine:

In accordance with our telephone conversation I am sending you herewith the paper by Mr. Vincent Schaefer on "The Production of Ice Crystals in a Cloud of Supercooled Water Droplets". I understand that you will be able to use this before the end of November. We will want reprints, of course, and when the galley proofs are returned the number can be indicated.

I will be away after tomorrow until November 4. If you need to communicate with us regarding the article during that period, I would suggest that you write directly to Mr. Schaefer. Also, we have a news release on this work which we want to issue about the same time this paper appears. As soon as you have set a definite date, I would appreciate your notifying Mr. George Griffin, manager of our News Bureau, whose address is 505 State Street, Schenectady 5, N.Y. In our release, we will, of course, state clearly that the work is being announced in "Science".

We appreciate your cooperation.

Very truly yours,

James Stokley:cr
cc: Mr. V. Schaefer
Mr. G. Griffin

Encl.

THE PRODUCTION OF ICE CRYSTALS IN A CLOUD OF SUPERCOOLED WATER DROPLETS

~~BY~~

Vincent J. Schaefer
General Electric Research Laboratory, Schenectady, New York

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Research Laboratory
General Electric Company
1 River Road, Schenectady 5, N.Y.

supercooled cloud in the cold chamber. Under normal conditions in the chamber, the cloud persists for periods ranging from ten to twenty minutes, the life of the cloud depending primarily on the evaporation and diffusion of the water droplets onto the ice-coated walls of the well. In addition to permitting these various types of ''commercial'' dusts to enter the cold chamber, many experiments were conducted in which samples of various types of fine particles were intentionally added to the supercooled cloud. Carbon, graphite, oil, sulphur, magnesium oxide, volcanic dust, talc, silicates, silica, diatomaceous earth, and many others were introduced as aerosols in an attempt to force the supercooled droplets in the cloud to crystallize.

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1. A Method for Making Snowflake Replicas. Vincent J. Schaefer. Science. 93, 239-240. March, 1941.

   Use of Snowflake Replicas for Studying Winter Storms. Vincent J. Schaefer. Nature. 149, 81. January 17, 1942.

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Fig. 1

Fig. 2

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(6) 1. Schaefer, Vincent J. Science, 1941, 93, 239; Nature, Lond., 1942, 149, 81.

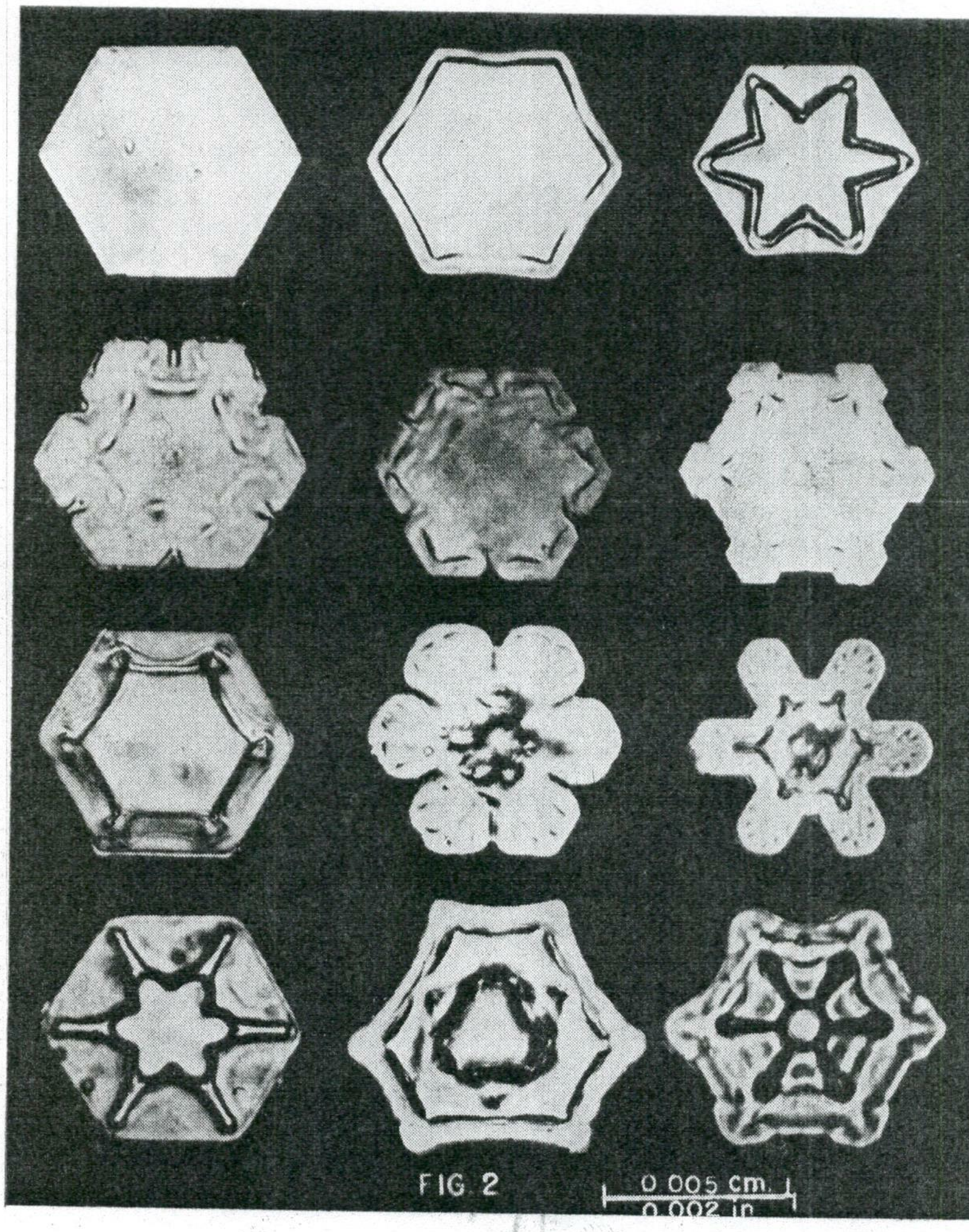

FIG. 2

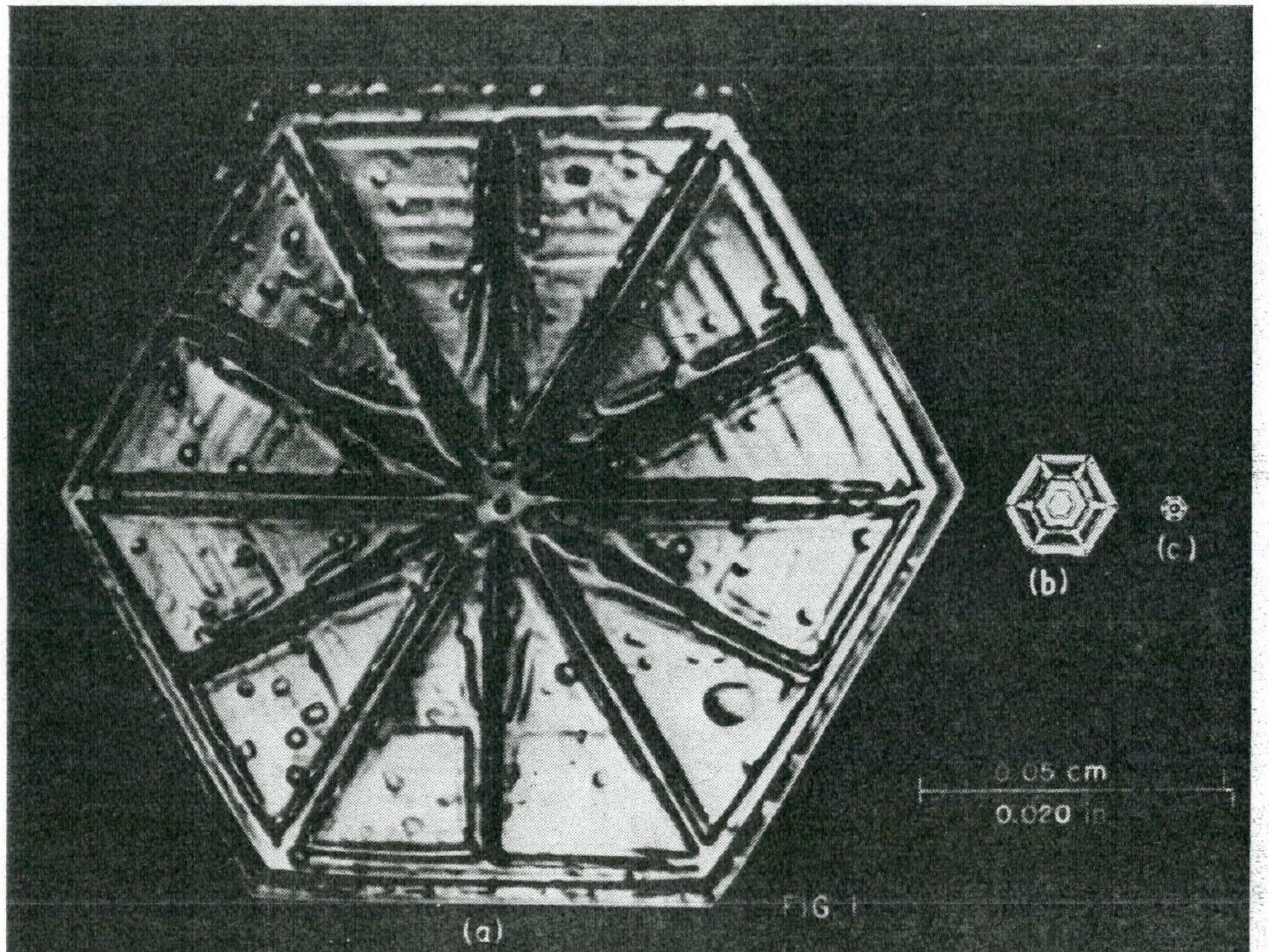

FIG. 1