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"SNOW AND CLOUDS IN THE SKY"

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Two of the most beautiful creations in nature are the clouds that float across the sky and snow crystals which form there and fall gently to the ground. For many centuries man has considered these things first of necessity; later as objects which lent themselves to poetic and philosophical considerations, and finally, at present, because of their intimate relationship to many of the practical aspects of what we like to term modern civilization.

While a lapse of many centuries exists between the time when deep snow restricted the movements of our cave dwelling ancestors, snow still retains its power to slow down our activities; sometimes, with our heavily mechanized civilization, to an embarrassing degree.

Snow on the ground has always had an effect on transportation, but until recently snow in the sky was no problem. During the war, a trouble known as "precipitation static" became a serious hazard in the safe flight of large planes through snow storms. It was observed that whenever planes entered areas containing snow, the radio equipment in the plane developed serious noise levels due to static. This static often became so bad as to render useless all radio communication, channels, and direction beams. When severe, the effect was most spectacular, with huge electric sparks or coronas streaming from the wing and propeller tips and other portions of the plane. The loss of air to ground radio communication and direction beams in extensive storm systems is a most serious problem, especially since these instruments are sorely needed when visibility is reduced to zero.

Early in the war several of us in the Research Laboratory were asked to join in a study of some of the basic problems related to "precipitation static" as produced by snow. Similar effects are also encountered in certain types of rain and dust storms.)

To carry on our studies, simple laboratory facilities were established on top of the Research Laboratory at Schenectady, at my home in the hills west of Schenectady, and at the Mt. Washington Observatory in New Hampshire at an elevation of 6,300 feet above sea level.

A number of physical and electrical properties of snow were determined at these three places by studying both single snow particles and the general effects produced by large numbers of them in a storm.

A study was made, for example, of the electrical charges carried by individual snow crystals falling from the sky, to see if these charges could explain the development of snow static. This experiment was made by permitting snow crystals falling from the sky to pass between two parallel plates charged to 18,000 Volts. The path taken by the crystals as they passed between the charged plates was photographed, and a simple measurement and calculation established the quantity of electricity carried by the individual particles. It was soon established that the quantity of electricity carried by free falling snow was far too small to produce the charging currents responsible for snow static.

Other observations showed that much of the static electricity was generated by the fragmentation of the snow particles as they were hit by the propellers, or struck the leading edge of the wing at high velocity. It was found that a single crystal would break into hundreds of fragments when it hit a metal surface at a velocity of a hundred miles an hour. As the tiny fragments of the broken crystals bounce and skid across the surfaces of the plane, they produce static electricity similar to that which develops when a glass rod is rubbed with silk or wool cloth. In an ordinary storm a B-29 intercepts about a billion snow particles during every second of flight through the snow area.

In the course of part of our studies, it became desirable to sample the snow crystals while the plane was flying through the storm area. While this may sound like a difficult problem, it actually was quite easy to do. Using the snow crystal replica technique which I devised in 1940, we constructed a device known as an air decelerator. By "spilling" the 200 mile an hour wind just ahead of the nose of the plane with a group of expanding louvers, the air was slowed down to about 30 miles an hour. When a snow crystal passes into the mouth of the decelerator, it is not deflected with the air but acts like a tiny projectile and continues through it and into a chamber of quiet air. Entering the quiet air the crystals are slowed down by air friction and at the end of their range fall gently onto a plate coated with a dilute solution of the resin known as

Formvar. This resin, when kept below the freezing point of water, does not affect even the most fragile parts of a delicate snow crystal. After being wet by the solution, the solvent evaporates, leaving the snow particle encased in a thin plastic shell whose inner surface retains all of the microscopic detail of the original crystal. This plastic shell forms within a few minutes. It may then be warmed. The residue from the melted crystal readily passes through the thin shell leaving a hollow cavity which scatters and reflects light in a manner quite similar to the original crystal.

The replica method has recently been very useful to us in our laboratory studies of the production of snow in supercooled clouds. It enables us to measure the relative efficiencies of various methods of producing ice nuclei, and also permits the easy study of the crystal forms produced by these different methods. Our laboratory crystals are often so small that they would quickly evaporate under the light needed to prepare photomicrographs of them.

Snow crystal replica solutions are now enroute to the snow slopes of the Himalayas in northern India, down to Antarctica with the Finn Ronne Antarctic Expedition, and into the mountains of Norway where scientists plan to sample the falling snows to learn more about the crystalline forms characteristic of these interesting regions.

In 1944, we were asked by the AAF to continue our work on Mt. Washington in the field of aircraft icing. This work was done in close cooperation with the Mt. Washington Observatory, where much of the pioneering work on the fundamentals of the icing problem were initiated.

The terrific winds, intense cold, and dense, supercooled clouds that sweep over the summit of the mountain a good part of the time from September until July make it an ideal place to study ice producing clouds under conditions which often closely approach those found in the free air. The great advantage of studying icing on Mt. Washington is that the investigator on the summit is in no danger of being in a plane crash no matter how severe the icing might become. While there is some danger from flying ice fragments and sometimes in reaching the summit if overtaken by a sudden storm, the Observatory is an ideal place for studying clouds.

One soon learns that the beautiful cloud structures seen in the distance lose much of their poetic properties upon close contact. They become either wet or icy, with low visibility, occasional lightning discharges and contain either blinding snow, driving rain, or perhaps a mixture of these and stinging sleet particles.

To learn more about the properties of clouds, one must consider the primary particle. Except for the cirrus clouds, which consist of tiny ice crystals, practically all other clouds are made up of water droplets even though they may exist in air far below the freezing point. When ice crystals develop in these types of cloud forms, they rapidly disintegrate, producing snow areas in the region originally occupied by the clouds.

When an aircraft enters a supercooled cloud, many of the droplets in the path of the plane do not follow the flow of air over the propeller blades, wings, and fuselage but instead contact the cold surface of the plane. Upon touching these surfaces the water droplets freeze to form various types of rime, or ice, depending on the velocity of the plane, the size of the cloud droplets, the surface condition of the plane or propeller and its temperature.

In considering various properties of clouds, two of the most important are the quantity of condensed water in them and the size of their deoplets. These properties vary widely. For instance, the condensed water in an ordinary valley fog, covering a square mile and reaching from the ground to the tops of the telephone poles, amounts to about a gallon of water, while the same volume taken from a dense cumulus cloud would fill a rain barrel to overflowing.

The wide range in liquid water content of clouds is related in a considerable degree to the size of the individual cloud droplets. Those which we commonly find when we go into the clouds range in size between five and 100 microns in diameter. Particles larger than this can hardly be called cloud droplets since they are heavy enough to fall toward the earth as a misty rain.

The smaller stable cloud droplets have a diameter about one tenth that of a human hair. About a hundred million of these must combine to form an ordinary rain drop.

In stable clouds the particles seem to be very uniform. Under other conditions, the range in size is very large.

We have developed several methods for measuring the size of cloud droplets. Tiny glass plates or cylinders coated with soot, water sensitive dyes, or a molten layer of vaseline are exposed for a fraction of a second to a passing cloud. This may be done from a plane, on a mountain summit or in a ground fog. The cloud droplets affect the coated slides leaving circular marks which are related to the size of the droplets. With the molten vaseline the droplets are entrapped as it cools leaving tiny spherical droplets or cavities which are of the exact size of the actual droplets. One of the most reliable and commonest methods in use at present was developed at Mt. Washington by the Observatory and our Laboratory. A group of cylinders ranging in size from 1/16" to 3" are mounted one above the other and turned slowly with a motor while exposed to the passing clouds. Metal cylinders are used in supercooled clouds and porous clay cylinders at temperatures above freezing These cylinders are exposed for periods ranging from four to twenty minutes depending on the density of the clouds. The increase in weight of the different size cylinders are measured after exposure, and this data is used to determine the liquid water content, the average diameter, and the distribution of droplet sizes in the cloud system to which it was exposed.

For getting more detailed information, a cloud meter was developed in our Laboratory. This consists of a tiny porous metal plug mounted so that cloud particles contact its outer surface. By maintaining a suction on the rear of the plug, every cloud droplet touching the outer surface is drawn into it. As the droplets continue to contact the surface the cloud water forms as a small droplet on the end of a capillary tube. When this grows to a certain size, it touches another tube designed to remove the droplet. This second tube is insulated from the first and as the gap between the tubes is momentarily bridged by the water droplet, an electric current flows and actuates a recorder. The sensitivity of the cloud meter may be adjusted so that it provides a detailed second by second record of the liquid water content of clouds, either on mountains or planes, in wind tunnels, or ground fogs. Work is now underway to adapt the cloud meter to also provide particle size data.

When we know more about the physical properties of clouds and the natural processes which cause changes in them, we will be in a more favorable position to predict the development of rain or snow or the potential icing hazards contained in them. Our present ability to convert supercooled clouds to snow opens new vistas to the study of clouds. The production of precipitation, the dissipation of ground fog, and the elimination of icing hazards in the sky depends to a major degree on our ability to obtain a better knowledge of the various cloud types that are in the atmosphere.

At present we are engaged in a cooperative effort with the U.S. Army Signal Corps, the Air Forces and the Navy in a fundamental research program to learn as much as possible about all kinds of clouds. No one knows where this research will lead us to, but it is obvious that we have much to learn about these elusive but fascinating structures in the sky.