ICING STUDIES ON MT. WASHINGTON: AN HISTORICAL PERSPECTIVE

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A brief history of the establishment of the Mount Washington Observatory is presented, along with a description of both the Observatory's facility and the icing research which has taken place on the summit.

INTRODUCTION

The Mount Washington Observatory, which was founded in 1932 and is situated on top on New England's highest peak, is said by some to experience "the worst weather in the world". This expression was used by Dr. Charles Franklin Brooks, founder of the Observatory, as the title of an article that he wrote over 45 years ago (Brooks, 1940). Dr. Brooks was professor of Meteorology at Harvard University in Milton, Massachusetts and a co-founder of the American Meteorological Society. In part, he states: "Thus it appears that while we cannot claim that Mount Washington is at times colder than anywhere else on earth, the severity of its climate at the worst seems to be equaled or slightly exceeded only on the very highest mountains of middle or high lattitudes and in Antarctica's 'home of the blizzard'." Continuing: "It is probable that there are worse mountains than Mount Washington, but observations do not seem to have been made upon them."

There are two principal reasons why Mount Washington is known for the severity of its weather. The first is simply that the summit is manned yearround and the weather monitored continuously, a detailed record being kept of its extremes. Second, Mount Washington, the highest peak in the Presidential Range lies at the juncture of the three principal storm paths and air mass routes of Eastern North America -- along the St. Lawrence River Valley, up the Ohio River Valley, and up the eastern coast of the United States. This activity occurs in the presence of the well-known Bernoulli effect, according to which air masses speed up as they pass over mountain ranges. This condition favors high winds and severe icing.

From the beginning, scientists came to the summit to conduct research, and many remained associated with the Observatory. For example, the roster for 1959 includes Wallace E. Howell, the President of the organization after Brooks' death, Luis Aldaz, Roland Boucher, Huntington Curtis, Joachim Kuettner, and Ronald Lavoie. In other years, Raymond Falconer, Robert Cunningham, Vincent Schaefer, and Myron Tribus were involved. The current staff has a somewhat more diversified background that reflects interest in related fields as well as the continuing concern with meteorology. Furthur information on the history of the Observatory may be found in Smith 1982a, 1982b.

SUMMIT WEATHER

Mean annual precipitation at the Observatory over the 48-year period 1935-1983, was 89.92 in (228.4 cm) and mean annual snowfall was 245.1 in (622.6 cm). The national snowfall record was once broken during the period September 1968 -- May 1969, when a total of 566.4 in (1438.7 cm) fell. The summit is in cloud or fog about 60% of the time. Maximum temperature has never exceeded 72 F (22.2 C), and the lowest recorded temperature is -47 F (-44.0 C). The yearly average is 26.6 F (-3.0 C), the lowest for the 48 contiguous states. (Brennan, 1981)

Winds at the summit come primarily from the West and Northwest, and can be highly variable. The annual wind speed on the summit averages an impressive 35.1 mph (15.7 m/sec). The most famous statistic, however, is the peak gust. On April 12, 1934, the wind reached a peak speed of 231 mph (103.3 m/sec) -- a world record which still stands. Also recorded on that day were a 5-minute average of 188 mph (84.0 m/sec), and an hourly average of 173 mph (77.3 m/sec).

The combination of high wind and frequent occurrence of supercooled fog make this site particularly well suited for icing research.

ICING RESEARCH ON THE SUMMIT

Research emphasis at the Observatory has changed somewhat over the years. The earliest research was weather or radio oriented. For example, standard synoptic weather observations were conducted for the U. S. Weather Bureau, turbulence in the lee of the mountain was studied (inadvertently) with hydrogen balloons, and there was considerable experimentation with precipitation gages that would work satisfactorily in the high winds prevailing on the summit. Radio research included landmark discoveries in the use of the five-meter band.

Within a few years, however, it became obvious that the summit provided excellent exposure to study the physical properties of clouds and, in winter, the mechanism of rime icing. Study of the properties of supercooled clouds by the measurement of rime deposition on a variety of collectors was begun at the Observatory in the 1930's. Later, Dr. Irving Langmuir, of General Electric Research Laboratory, became interested in the subject while engaged in research on precipitation static for the Army Air Forces in 1943. His work culminated in droplet trajectory studies with a differential analyzer (Langmuir and Blodgett, 1946) that are the basis both of the present multicylinder method and of all subsequent droplet trajectory work. (Howe, 1960) The droplet trajectory studies were repeated, extended and refined at the NACA Lewis Laboratory, and the theoretical curves produced then are used in the analysis of multicylinder data today. (Brun and Mergler, 1953; Brun, et al, 1955)

A variation of the multicylinder device developed at the Observatory by Langmuir and his colleagues is still in use (Figure 1). At the present time the Observatory is comparing multicylinder data with data gathered by a Forward Scattering Spectrometer Probe (FSSP).

During the 1940's and 1950's various icing studies were completed on the summit. They were sponsored by a variety of contractors: the U. S. Weather Bureau, General Electric, the Air Materiel Command, NACA, and the U. S. Army Signal Corps. An expanded chronological listing of research projects completed on the summit may be found in Table 1.

Antenna icing studies, mostly in the form of survival testing in the harsh summit environment formally began in the early 1960's and continue today (Figure 2) as do measurements of the physical properties of clouds (Figure 3). Other work during this period involved the testing of ice-releasing surfaces, microwave antenna deicing and the development of the Observatory's heated aircraft pitot-static type anemometer.

The most recent period of research, from the 1970's to the present, has seen the development of a great variety of icing research programs on the summit. From the exposure and testing of both hot wire and propeller-type anemometers (Figure 4) and wind and ice probes (Figure 5) to the collection of rime on simulated power lines (Figure 6), the Observatory has committed itself to increased involvement in this field, and applies computer and video technology wherever appropriate.

THE OBSERVATORY TODAY

The Observatory is currently housed in the west end of the Sherman Adams Building, a steel-reinforced, concrete structure located on the summit (6288 ft/ 1917 m) completed by the State of New Hampshire in 1980. Scientific and observational facilities, consisting in part of a photographic laboratory, radio/electronics research test and repair facility, research library, workshop, and computer system, along with crew living quarters, lie beneath the tower, which rises to 6309 ft.

Primary access to the summit is via the Mount Washington Auto Road, using the Observatory's truck in the summer, and its own tracked snow vehicle during winter when travel is restricted. The traverse is through some of the most spectacular scenery in the northeast; however, trips are always subject to postponement on account of weather.

The Mount Washington Observatory relies on research contracts and upon its members, both private and corporate, for its support. The facilities and staff of the Observatory are available on a contract basis. For further information about the Observatory, contracting procedures or membership, please write: Observatory Director, Mount Washington Observatory, Gorham, NH 03581.

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Table 1: Icing research programs on the summit of Mt. Washington from 1943 to the present.

Project	Sponsoring Organization	Date
Jet engine icing	U.S. Air Force	1943
Cloud properties	General Electric/U.S. Air Force	1943
Development of Multicylinder	Mt. Washington Observatory	1940's
Rime studies	U.S. Weather Bureau	1941-43
Icing studies	U.S. Weather Bureau	1944
Aircraft icing	General Electric	1944-45
Icing research project	Air Materiel Command	1946
Icing instrumentation	Nat. Advsy. Comm. Aeronautics	1950-52
Snow crystal study	U.S. Signal Corps.	1955-58
Antenna icing	D. S. Kennedy Co.	1960
Antenna icing	Raytheon	1962
Antenna wind loading	Lockheed	1965
Devel. of pitot tube anemometer	Mt. Washington Observatory	1965-72
Ice-releasing coatings	Cold Regions Res. & Eng. Lab.	1967-68
Freeze-thaw measurements	Cold Regions Res. & Eng. Lab.	1968
Icing on aircraft wings	General Electric	1970
Plastic-coated 3-cup	MAXIMUM, Inc.	1971
Snow fall/depth in high wind	Mt. Washington Observatory	1971
Heated, recording wind vane	Mt. Washington Observatory	1971
Radome deicing tests	Cold Regions Res. & Eng. Lab.	1971-72
Ice detector for Auto Wx Station	NOAA	1972
Microwave antenna deicing	Microflect, Inc.	1972
Helicopter rotor icing	Cold Regions Res. & Eng. Lab.	1976-77
Helicopter icing tests	Cold Regions Res. & Eng. Lab.	1977-78
Ice and wind loads on cables	Cold Regions Res. & Eng. Lab.	1977-78
Photovoltaic cell testing	M.I.T. Lincoln Lab	1977-82
Cable icing	Cold Regions Res. & Eng. Lab.	1979-pres
Propeller anemometer test	R.M. Young	1983-84
Icing detector evaluation	Dataproducts New England	1983-pres
Tower icing	NRG Systems, Inc.	1983
Antenna survival test	Motorola, Inc.	1984-pres
Hot wire anemometer evaluation	Environmental Insts. Inc.	1984-pres
Antenna survival test	Allgon Antenna Corp.	1984-pres
Wind and ice probe evaluation	Franklin Engineering Corp.	1985-pres
Snow crystal and droplet samp.	U.S. Naval Academy	1985

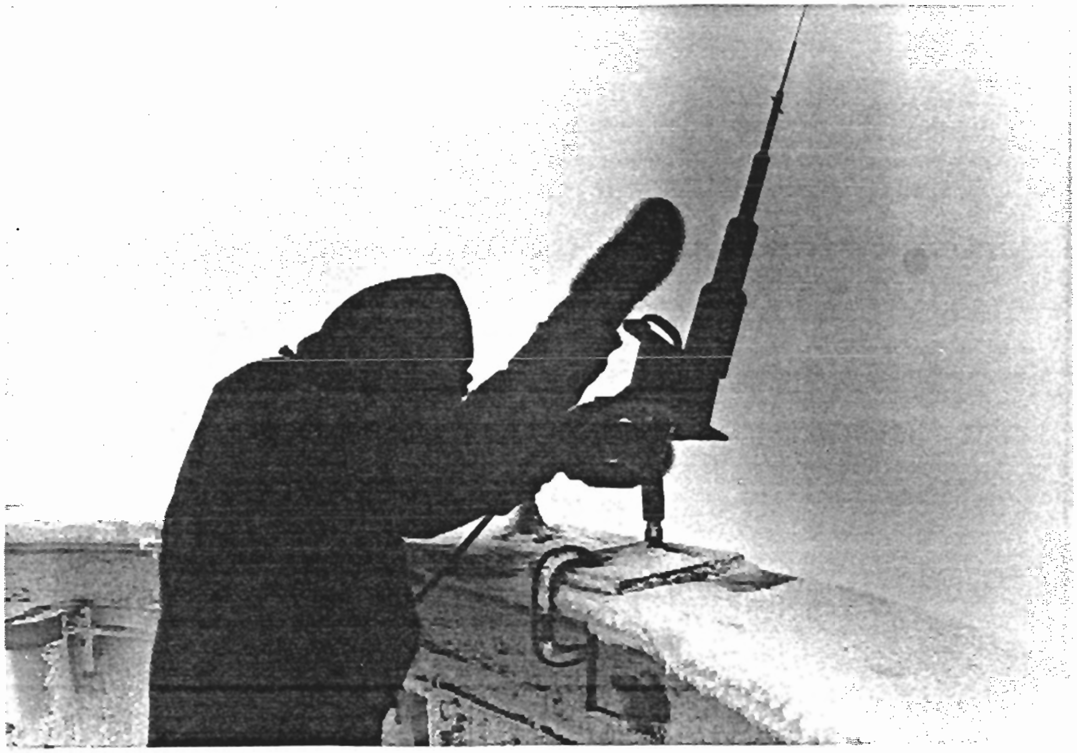

Figure 1: John Howe, Staff Engineer, employing the multicylider device on the tower railing.

Figure 3: U.S. Naval Academy Prof. W. Hindman and an assistant collect samples of ice and snow crystals on the roof of the Observatory.

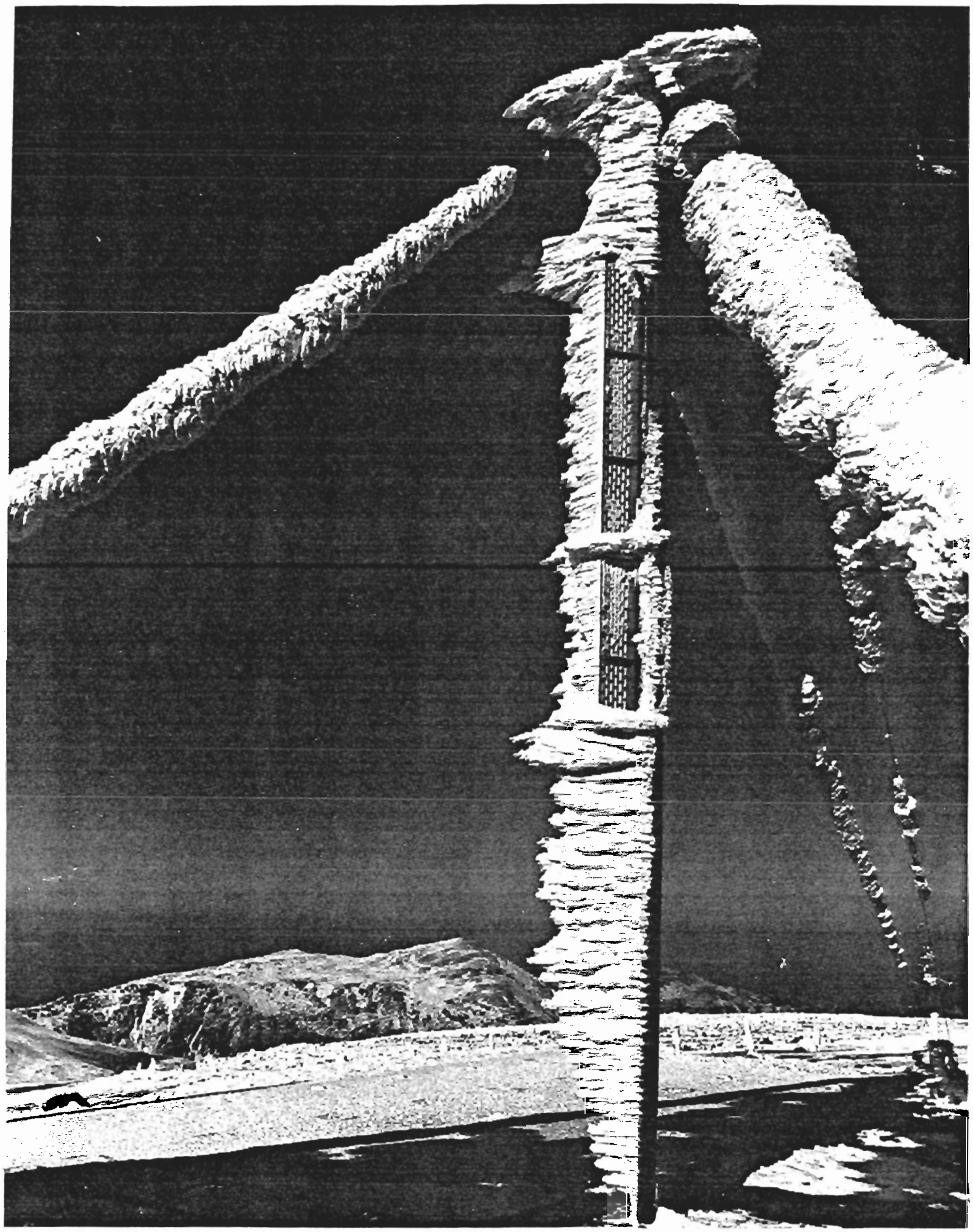

Figure 2: Allgon Antenna Corporation antenna under moderate ice load.

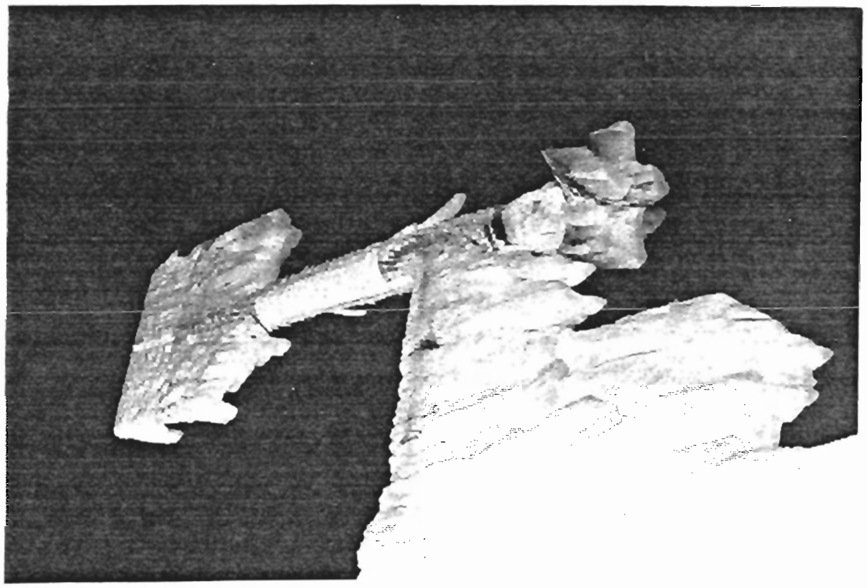

Figure 4: The R. M. Young unheated propeller type anemometer and wind vane with a heavy coating of rime ice. This test required running to destruction.

Figure 5: Chuck Franklin of Franklin Engineering installing his pneumatically deiced wind and ice probe on the tower super-structure. Two D. N. E. ice detectors are also visible.

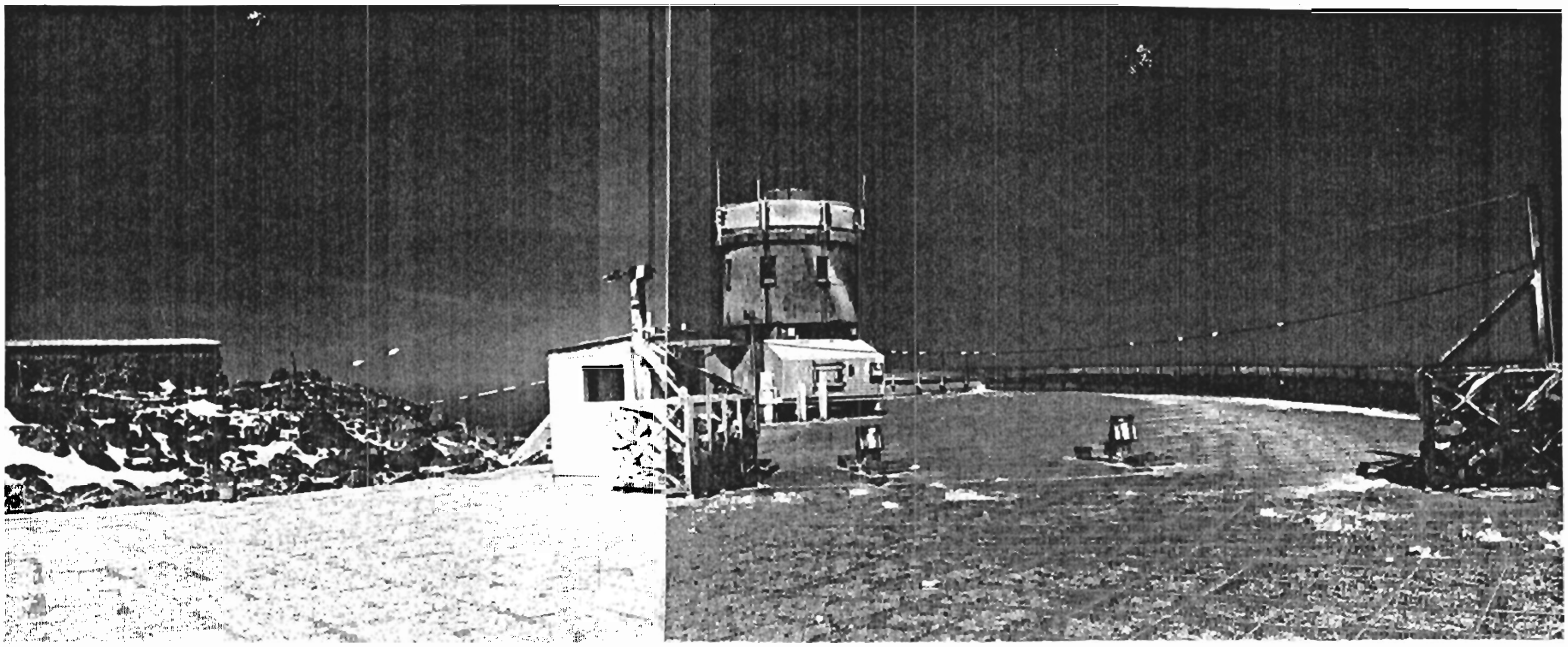

Figure 6: View of the CRREL wire configuration and instrument shelter on the roof of the Observatory.