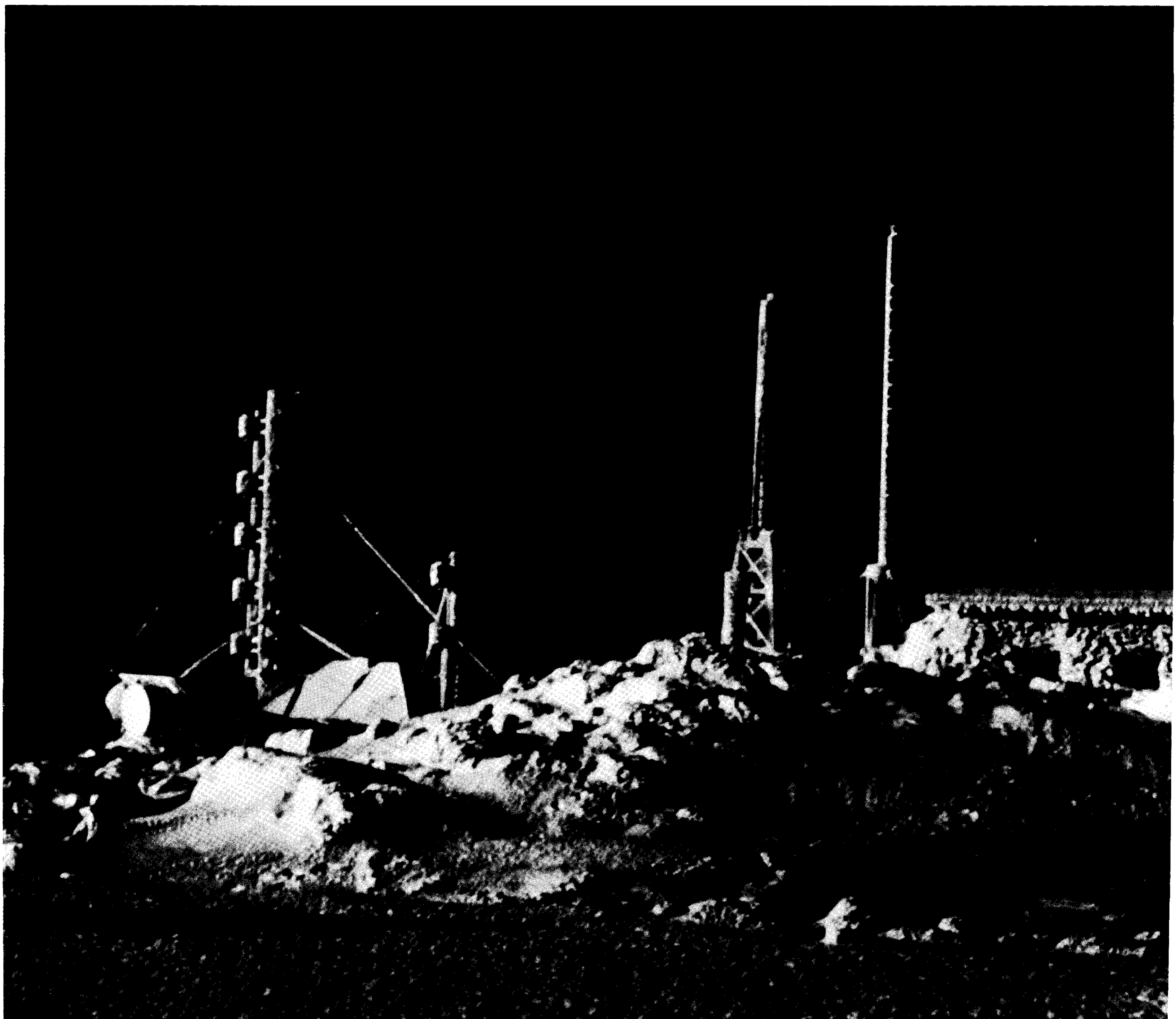
# CRREL

# REPORT 86-17

US Army Corps
of Engineers
Cold Regions Research &
Engineering Laboratory

# *Atmospheric icing on communication masts in New England*



CRREL Report 86-17

December 1986

# *Atmospheric icing on communication masts in New England*

Nathan D. Mulherin

Prepared for
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Rime icing and freezing precipitation are of concern to the radio and television broadcasting industry. This report contains the results of a study seeking to document the severity and extent of transmitter tower icing and related problems in the northeastern United States. Information was obtained via mail questionnaire and telephone interviews with 85 station owners and engineers concerning 118 different stations. Results show that television and FM broadcasters are seriously impacted by tower icing; however, AM operators are usually not affected by expected New England icing levels. Combined annual costs for icing protection and icing-related repairs averaged $121, $402 and $3066 for AM, FM and TV stations respectively. None of the AM stations polled employ any icing protection measures whereas all the TV stations do. The percentage of FM stations having icing protection in the three northern states averaged 80%, indicating a significant concern for icing in that region. In contrast, the percentage of FM stations with icing protection was 63.5% for the southern New England states. The usage of guyed versus non-guyed towers was a poor indicator of icing costs. However, the factors of increasing mast height and mast top elevation are significant to increasing costs. The data show that stations with mast

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heights greater than 275 m (900 ft) and top elevations exceeding 760 m (2500 ft) above mean sea level are at risk and need icing protection. Ocean proximity seemed to have a moderating influence on icing: average costs were $341 for FM stations within 5 km of the coast, versus $472 per year for all FM stations with icing protection. Annual icing costs for all AM stations averaged $121 compared to $75 for coastal AM stations. Current methods of icing protection and their efficiency are discussed herein.

## PREFACE

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# Atmospheric Icing on Communication Masts in New England

NATHAN D. MULHERIN

## INTRODUCTION

Much research has been conducted on the phenomenon of atmospheric ice accretion on structures. However, relatively little investigation has focused on the problem specific to television and radio transmission disruption. Atmospheric icing of radio and television towers has long been recognized by broadcasters as a source of numerous problems. These problems range in severity from transmission distortion (which may or may not be significant) to complete tower collapse, and include structural fatigue, stretching and wearing of guy lines, and equipment damage from falling ice. Ice sometimes forms between antenna radiating elements, causing electrical shorting and equipment burnout. Installations near populated areas have the added liability for falling ice damage to life and surrounding property.

This report presents summarized information obtained through telephone and mail inquiries to 85 owners, engineers and other station personnel throughout New England regarding their experiences with atmospheric icing. The purpose of our inquiry was to assess four areas of interest:

1. The industry's concern regarding ice accretion on towers
2. The current methods used to prevent or control disruption to normal operations
3. The success of these methods
4. The influence of geographic, topographic and climatic factors on the severity of icing on these structures.

## BACKGROUND

### Types of accretions

For maximum radiating capability, radio and television antennas are often situated in elevated locations that are subject to wind and storms. Exposed structural members provide a site for the accumulation of supercooled moisture from the atmosphere and subsequent icing. Two sources of atmospheric ice accretion are recognized: 1) in-cloud icing, where the supercooled droplets are small enough to remain suspended, and contact with a surface is brought about by air movement; 2) precipitational icing, where the droplets are massive enough to fall from the atmosphere onto the accreting surface. Precipitational icing may give rise to either rime or glaze ice buildup. In-cloud icing, however, can produce these and a third condition known as "frost." Frosting occurs during very quiet air conditions whereby a surface collects moisture from the air directly from the vapor phase. The resulting growth of fine-crystalled ice is usually slight in thickness due to the limited availability of moisture at low temperatures and to a low vapor flux to the surface with the lack of air circulation. Frosting creates no major problems in broadcasting and will not be considered further in this study.

Glaze ice is usually the product of freezing rain or of airborne spray from nearby bodies of water (precipitational icing) accreting at relatively high temperatures (0° to −3°C). It appears on surfaces as a tightly bonded, clear, glass-like coating, and is very dense ($\geq 0.9\ Mg/m^3$, the density of pure ice being 0.92). It may or may not be uniform in thickness because icicles often form on the underside of an object as the water flows before freezing. The factors which favor its formation are large droplet size, rapid accretion rate, low degree of supercooling, and slow latent heat dissipation after contact. This type of icing is the most serious threat to structures due to its density and the large additional loads it can impart. Damage from falling ice and tower failures is most likely to occur during and after glaze ice storms.

Rime formation occurs more frequently in mountainous areas than does glaze and therefore

**Table 1. Types and properties of atmospheric ice. After MEP Limited (1984), Minsk (1980) and Makkonen (1984).**

| *Types of ice* | *Appearance* | *Density* *($Mg/m^3$)* | *Conditions* |
|---|---|---|---|
| Glaze | Clear, smooth, hard ice, tightly bonded to surface. Usually icicles present. | > 0.9 | Air temperatures near 0°C, windspeeds of 1-20 m/sec, surface temperature of accreting surface = 0°C. |
| Hard rime | Hard, granular white or translucent ice growing outward from the windward side of accreting surface. | 0.6–0.9 | Air temperatures approximately -3 to -8°C, windspeeds of 5–10 m/sec, surface temperature of accreting surface < 0°C. Droplets flow and coalesce somewhat before freezing. |
| Soft rime | Opaque-white, feathery, granular ice, loosely bonded and growing outward from the windward side of accreting surface. | < 0.6 | Air temperatures approximately -5 to -25°C, windspeeds of 1-5 m/sec. Supercooling rate is high enough that droplets freeze immediately on contact. |

the total number of damaging events, while less serious, is probably higher for rime. Rime ice varies from "soft" to "hard" depending on its density, clarity, and crystal structure. Its formation is favored by small droplet size, slow accretion rate, a high degree of supercooling, and rapid dissipation of latent heat. Soft rime forms at lower temperatures (-5° to -25°C) and low windspeeds (1 to 5 m/s). The impinging droplets freeze very quickly, trapping air as the accretion grows. The large amount of entrapped air is responsible for its opaque-white and fluffy appearance. Close examination often reveals a delicate needle-like or dendritic structure. Due to its lower density (0.6 $Mg/m^3$ or less), soft rime is a lesser problem for broadcasters. Hard rime, on the other hand, is intermediate to glaze and soft rime in terms of its density, clarity, and hardness. It is formed at more moderate temperatures (-3° to -8°C) and higher windspeeds (5 to 10 m/s). The impinging droplets flow somewhat before freezing, which creates a smoother appearance. The slower freezing rate allows less air to be entrapped as the ice is forming, resulting in a translucent, denser structure (0.6 to 0.9 $Mg/m^3$). The preceding descriptions of the various accretion types are summarized in Table 1.

Bennett (1959) points out that icing on structures is not limited to only one type. Instead, surface features such as shape, exposure, heat dissipation characteristics, etc. can contribute to the buildup of various ice types.

## Problems caused by icing

Rime icing and freezing precipitation annually cause many thousands of dollars in damages to stations in New England. Transmitter tower icing is a normal component of operating costs for most broadcasters in northern latitudes. However, an acceptable level of risk must be decided upon in balancing initial construction cost against future maintenance. Generally, station engineers must devise their own icing protection based on field experience. Prior to construction, one may use the Electronic Industries Association (EIA) Standard RS-222-C or a number of other available reports which discuss design load calculations (Glukov 1971, 1974, Williamson 1973, Chaine et al. 1974, Chaine and Skeates 1974, Zavarina et al. 1977). Design loads are a combination of dead weight and wind load. Icing imparts additional dead weight to the structure and also presents a larger surface area to the wind. Since icing intensity and frequency are highly variable geographically, and data are usually lacking, the EIA code does not specify design loads. Two sections of the code are as follows:

> 2.1.5 Design load shall be the specified combination of wind, ice, and deadweight applied to the tower...
>
> 2.2.2 When ice is considered, it shall not be less than the minimum specified radial thickness on all members of the structure, including guys. Unless otherwise stated, ice shall be considered solid. (Note: This standard does not specifically state an ice thickness requirement ...)

The note following section 2.2.2 is important because the determination of a probable ice thickness is left to the designer. The difficulty arises in estimating an expected radial thickness value,

*Figure 1. Wreckage of WCSH-TV's (Portland, Maine) 1300-foot tower felled by severe icing on 9 March 1983.*

which is crucial for the calculations. Climatic records and site-specific considerations are used to estimate the likelihood of a worst-case combination of storm conditions. Icing intensity has been shown by numerous studies and case histories to be dependent on topography, microclimate, and accreting surface characteristics (Raevskii 1961, Lomalina 1977, Ahti and Makkonen 1982). There are also some published statistical analyses of climatic records that aid in forecasting regional icing expectation (Austin and Hensel 1956, Bennett 1959, Bilello 1971, Tattelman and Gringorten 1973). Ice load determinations for towers should therefore be the joint assessment of designer, field engineer, and meteorologist. The need exists for more complete data that define frequency and intensity and the effectiveness of protection measures so that engineers can better weigh costs and benefits of the various design alternatives.

Towers must be periodically surveyed for signs of structural fatigue from repeated ice accretion and wind loading, and guylines should be inspected for wear and retensioned to counteract stretching. Guyed towers are especially prone to failure from uneven shedding as can be seen in Figure 1. Heavy ice loading on the guys exerts tremendous tension on the system, and when individual guylines suddenly release a load, torsional forces can overcome the strength of the tower. Work is currently underway in Finland to gather data on tower stresses induced by natural icing (Lehtonen and Laiho, in press).

Harmonic oscillation of supporting guylines, or "guy galloping," is a rare but extreme type of stress that affects tall towers. At times, it can become severe enough to topple structures. It follows from a sequence of events that is highly specific to each particular guyline it affects. It has been proposed that a small amount of ice building up on the windward side causes a cable to assume the shape of an airfoil. A moderate wind can then induce the cable to move due to aerodynamic lift and drag phenomena (Edwards 1970). Galloping is produced when the movement matches the resonant frequency of the cable, resulting in increasing oscillation amplitudes. The danger lies in the fact that galloping usually affects only one or two lines of an entire guy system during any one event, which can produce violent twisting of the tower. An added danger is the fact that metal becomes more brittle and subject to failure when cold. Low frequency, high amplitude (LFHA) cable dampers are commercially available that purport to inhibit galloping. Parkinson and Santosham (1967) show that the critical wind velocity that produces galloping is equal to:

$$V_c = \frac{4\beta m\omega}{hA_1\varrho} \tag{1}$$

where $\beta$ = fraction of critical damping
$\omega$ = natural frequency of system
$m$ = mass per unit length of conductor plus ice
$\varrho$ = density of air
$h$ = transverse dimension of conductor plus ice
$A_1$ = constant related to the lift and drag characteristics of the ice conductor.

LFHA dampers are designed to increase the damping in the system as wind and ice loading occur. Translational motion of the cable also varies the damping and the resulting critical velocity. During a galloping event in December 1966, the engineer for WHDH Corporation in Boston, Massachusetts, successfully utilized this idea by hiring a large tow-truck to winch onto a guyline supporting his 400-m-high tower.

The dielectric properties of an ice coating can affect the antenna's RF wave propagation. Instead of signal propagation outward, some of the radiated power is reflected back into the antenna and the voltage standing wave ratio (VSWR, reflected power versus radiated power) is increased. The VSWR level must be kept within established operating limits. A little icing results in signal distortion and diminished power at the station's licensed broadcasting frequency. More icing can produce severe signal feedback and voltage overloading of circuitry. The VSWR level is monitored electronically, and when it reaches a preset threshold a warning system alerts station personnel so that corrective measures can be taken. Unlike that used for FM or TV broadcasting, VSWR for AM broadcasting is not as sensitive to ice buildup due to the longer wavelength of transmission; AM stations therefore rarely employ deicing measures.

Tall masts are also subject to damage from falling ice chunks shed from the upper levels. Vulnerable items include transmission lines, reflector dishes and antenna elements. Reports of missiles of considerable size and weighing tens of kilograms are common during shedding events. Icing and shedding are usually the result of specific storm patterns, and station personnel can often predict from past experience the onset of a dangerous situation. Knowing the likely storm track and the associated wind directions, ground-based support systems are situated normally to the windward side of the tower for protection from falling ice. The aforementioned vulnerable items, mounted at lower heights on the tower, are shielded from above with wood, sheet metal or wire frame construction. Transmitter roof buildings are likely to be constructed to absorb impacts and resist punctures. Even more serious is the threat posed by towers located in densely populated areas to surrounding life and property. In many instances, ice chunks have smashed through building and car roofs. Fortunately, few personal injuries have occurred in the past. The fear of such an occurrence, though, is reflected in the large annual cost of a station's liability insurance. Currently, falling ice damage is perhaps the most difficult problem to deal with because there are no feasible proven means of prevention available for tall masts. The best way to guard against damage to adjacent property is to restrict land usage in the icefall shadow of the tower. Initially, the tower should be constructed on a vacant parcel of land large enough to encompass the highly probable fall zone. Thereafter, land-use planners should be cognizant of the danger and restrict development in this zone.

**Prevention and shedding methods**

Many different approaches have been taken to prevent ice accretion, to minimize its severity, or to aid in its removal. These can be grouped as either anti- or deicing methods. Anti-icing methods minimize or prevent accretion, whereas deicing methods remove the ice once it has formed. Makkonen (1984) provides a summary of current technology in this area. However, there is not much literature pertaining to radio and television applications. Due to the large size of transmitting towers, many of the traditional anti-icing and deicing methods are not cost-effective. The following is a summary of available methods.

Atmospheric icing has been shown in theory to be diminished by increasing the diameter of superstructure elements, thereby reducing the collection efficiency of the surface. The collection efficiency is defined as the ratio of the mass of droplets impinging on the surface to the total mass that would have impacted if not for deflection of the airstream around the object. This idea has been utilized with success on arctic oil drilling platforms by enclosing the superstructure in a solid panelwork. Application of this concept to broadcasting is limited to short, sturdy towers where the additional wind loading would not be excessive.

Radomes are an example of the use of this principle. These are rigid covers constructed of polyurethane, fiberglass, or sheet metal which enclose the radiating elements of an antenna or the reflecting surfaces of a receiver. Although they improve the system's capabilities during an icing event, severe conditions can still present a problem as seen in Figure 2. The WMTW-TV tower at the summit of Mount Washington is an example of a tower radome (Fig. 3). Today, their primary antenna is mounted atop a 120-foot tower completely inside a steel tubular enclosure. The old tower, with steel framework exposed, now supports only their emergency backup antenna. During an icing event, the two adjacent towers provide a clear illustration of the new tower's diminished propensity to icing. In addition, outfitting radomes or exposed elements with a flexible sheathing has been successful at some installations. Flexure is caused either passively by wind and vibratory action, or by an active pneumatic system (Hartranft 1972, Ackley et al. 1973). In some cases the entire tower structure has been enclosed, but only after the danger of increased wind loading has been carefully considered. In general, only the radiating elements are enclosed.

Ice was removed from the guys of an antenna tower in Finland during the winter of 1981–82 using a common concrete vibrator attached to a guyline (Jaakola et al. 1983). The frequency used was reportedly 20–30 Hz. Recent laboratory tests conducted at CRREL produced evidence that a glaze ice layer on a steel beam was unaffected by con-

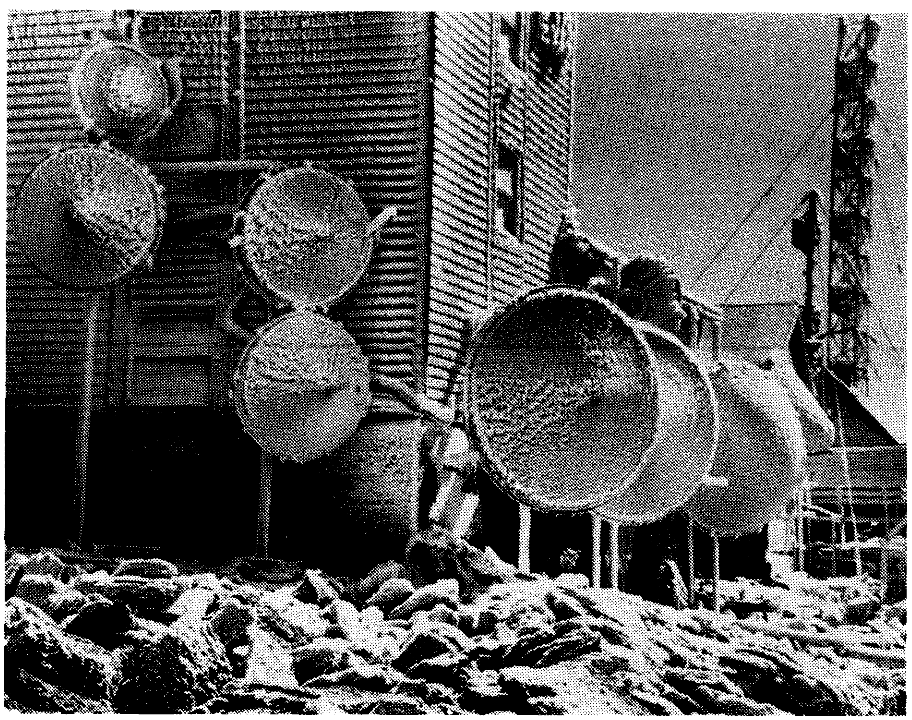

*Figure 2. Radomes over microwave relays following a riming event on the summit of Mt. Washington. Manual deicing of the radomes by on-site personnel using ordinary hand tools is often necessary.*

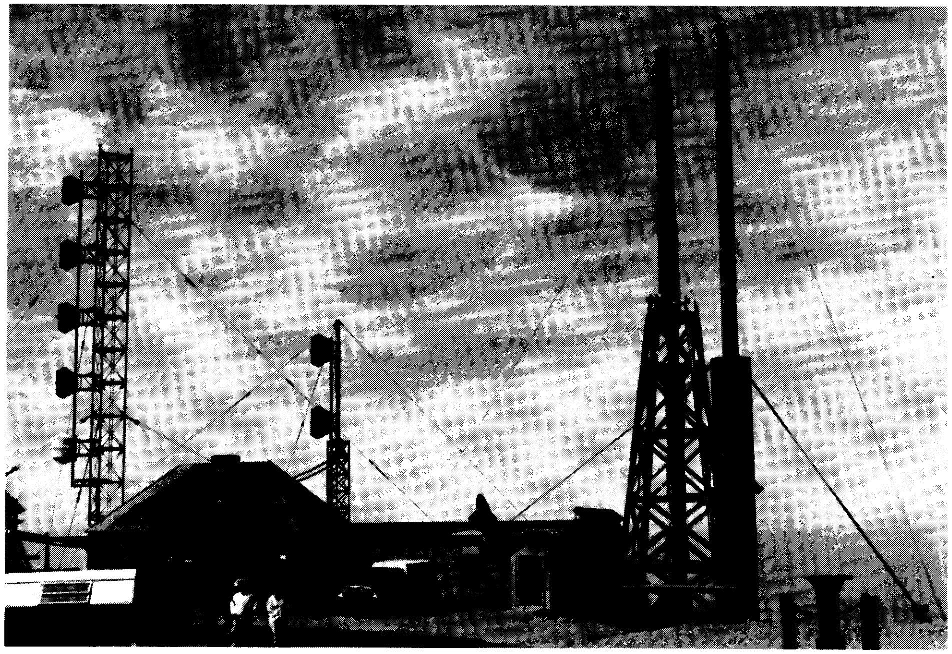

*Figure 3. Radio and TV towers at the summit of Mt. Washington. WMTW-TV's tower, shown at extreme right, is radome-enclosed and less prone to icing than their old tower with exposed framework.*

stant vibratory frequencies of 19 and 30 Hz (Donaldson 1985). The beam was a 2.44-m-long section of steel channel iron with cross-sectional dimensions of 25.4×6.6 cm. It was rigidly mounted and partially treated with a commercially available hydrophobic paint. However, sufficient amplitudes were produced to remove ice during the startup and shutdown of the vibrator when the beam passed through its characteristic resonant frequency. Mid-span beam displacement was approximately 1.6 cm at maximum amplitude. During the controlled coldroom tests, the vibrator successfully removed as much as 80% of a 2.5-cm-thick ice cover during a single 20-second cycle from start, to full speed, and back to stop. Tests conducted on various ice thicknesses in the range of 0.6 to 2.5 cm showed that the thinner layers were more difficult to remove. Although the amplitudes necessary to remove ice from stiff members may prove to be too extreme for a tower's structural integrity, the technique seems worthy of further testing, especially for guylines and less rigid towers.

Another approach to icing protection has been in the area of icephobic or low ice adhesion coatings. Sayward (1979) summarizes the theory from the standpoint of interfacial chemistry and presents a list of abstracts on the subject. Makkonen (1984) also gives a general summary of previous work. The types of coatings studied have been freezing point depressants and low wettability substances. Freezing point depressants, such as glycol solutions, soluble salt solutions, and gas-evolving coatings, function by contaminating the accreting droplets and reducing the freezing point below that of pure water. Sloping or vertical surfaces will then shed the liquid so ice doesn't form. Horizontal surfaces are more troublesome. As such, freezing point depressants are classified as "sacrificial coatings" because they are continually being washed away and must somehow be replenished. Highway salting and aircraft wing de-icing are common uses of these materials (Hanamoto et al. 1980, Itagaki 1984). Low-wettability oils, greases, and permanent coatings have been pursued because of their hydrophobicity. However, it is incorrect to assume that hydrophobicity implies icephobicity. During the early stages of icing, these substances allow the droplets to run off a sloping surface more rapidly before freezing can occur. Eventually some droplets accrete before they can be shed. In turn, these create sites for further accretion and the hydrophobic coating thereafter becomes rapidly coated with ice. Studies have shown that certain polymer coatings exhibit a lower adhesive strength for ice than bare metal surfaces (Phan et al. 1977, Jellinek et al. 1978).

Bulk-formed ice is less adhesive than that formed by impacting droplets, and higher windspeeds increase the adhesive strength of accretions. It is proposed that the impacted water penetrates more deeply into the surface roughness, creating a stronger mechanical bond upon freezing (Stallabrass and Price 1963, Phan et al. 1977). Panuishkin et al. (1974) showed a direct relationship between adhesive strength and surface roughness. Assuming that surface roughness increases over time through oxidation, erosion, ice shedding and damage from icefall, the useful lifetime of surface coatings is questionable.

The suitability of coatings for radio and TV towers is also debatable because of the dimensions involved. To date, no experimental work has been conducted that points conclusively to a family of coatings that will satisfy the requirements of durability, low cost, and simplicity of application. Clearly, to coat and recoat an entire mast structure is not an attractive anti-icing alternative. Numerous papers have suggested the possibility of using low-energy coatings in conjunction with other techniques to ease removal once ice has formed (Ackley et al. 1973, Makkonen 1984). It is conceivable that troublesome sections on towers could be coated for easier ice removal by natural or artificial means (wind, gravity, heat, vibration, impact, etc.). At least two station owners in our study believe that their icing problems are diminished because their antenna elements are polymer-coated.

The choice of paint color is another worthwhile consideration. Darker colors absorb more solar radiation and would therefore heat up to dislodge ice more rapidly following a storm event. During a storm, however, when there is little solar gain through fog and clouds, the amount of ice buildup would be equivalent to that on light colored elements. The value of color choice would be to speed the return to normal operations once the weather clears. Although the Federal Communications Commission requires that all towers be painted with a standard red/white pattern for greater visibility to air traffic, certain tower attachments and antenna elements could be darker for the solar gain advantage.

At the present time, the only totally effective anti-icing method available is heating, and it is the method of choice for most station owners in New England who employ icing protection. Calculations in the past have ruled out the possibility of heating the entire tower as much too costly. Makkonen (1984) cites the power requirement of 2 $kW/m^2$ for an icing rate of 3 $g/cm^2$ hr to prevent accretion on the steel superstructure of ships. Jaakola et al. (1983) mention attempts in Finland in 1974 to deice an antenna tower shaft and guylines by heating with heat cables. In this case, the power required to remove ice ranged from 50–120 W/m and a deicing period of approximately eight hours was required for difficult accretions. Given the large power demands, heating is, in general, only used to prevent icing of the radiating elements of FM and TV antennas. The popular heating units are factory-built into "batwing" or whip-type antennas and must be activated in advance of an icing event. These low-wattage heaters usually cannot keep up with the accretion rate if ice is allowed to accumulate appreciably before the heaters are activated. Some station operators manually activate heaters based on the local weather forecast or individual judgment. Others prefer the more cautious alternative of operating deicers for the entire season. A third alternative is to provide for autoactivation via thermal, precipitation, and/or icing sensors.

## RESULTS

### The survey

In the summer of 1984, approximately 25 radio and television stations were contacted by telephone to preliminarily ascertain their level of concern over ice accretion. No statistical considerations were made in selecting these stations. In fact, the majority were chosen specifically because problems were suspected due to the location or elevation of their towers. Based on the difficulties experienced by these stations, there clearly existed a need for better solutions, and a more thorough investigation was begun. In December 1984, we distributed a two-part mail questionnaire to all New England stations with mast heights greater than 50 feet. Predominantly short-answer, multiple-choice, and fill-in type questions were asked to ensure greater participation in the survey. Part 1 solicited general subjective data about icing and specific site descriptors for each location. The respondents were asked to provide brief summaries of their mast designs and to list all attachments and equipment thereon. The current use of any protection measures was questioned. The presence of any meteorological equipment at the site was

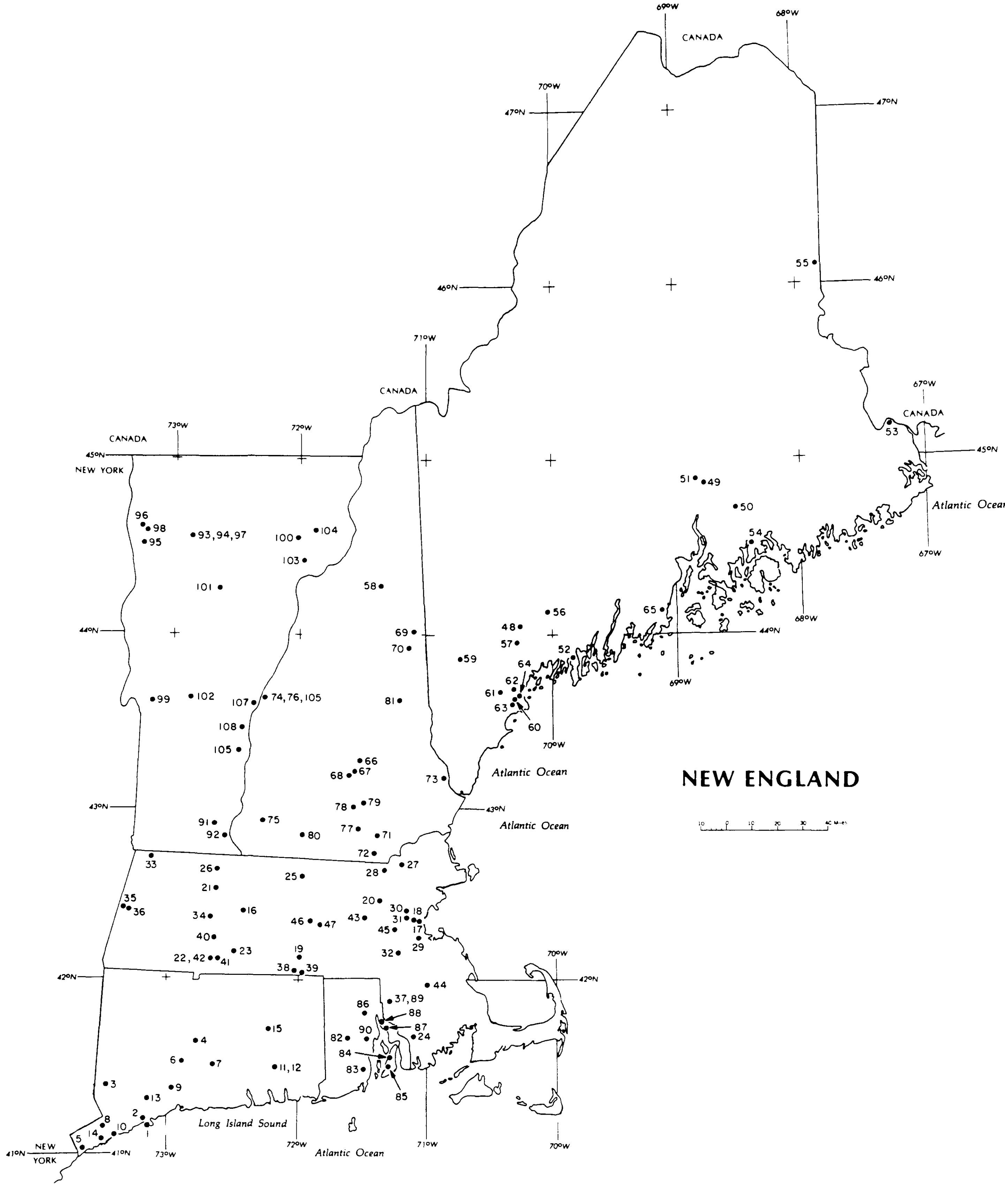


*Figure 4. Tower locations of all stations responding to the survey. For key to station number, see Appendix B.*

also of interest to allow measurements during a future icing event. A "General Icing History" portion listed various problems and urged subjective response on the frequency and severity of each that could be expected in a normal season. We also obtained average annual cost ranges for wind/ice damage repairs and for maintenance of protective equipment for each station.

Of the 432 questionnaires (Appendix A) that were mailed, 108 stations (25%) returned Part I by 1 April 1985. The information in this report is derived from the 108 responses and 10 AM- and FM-combination stations, totaling 118 when considered separately. The tower locations of all responding stations are shown in Figure 4.

Part II of our survey was a form whereby station personnel could report icing experienced throughout the 1984–85 winter. We were interested in obtaining dates and descriptions of the events as they occurred, along with concurrent meteorological parameters such as temperature, windspeed, wind direction, humidity, precipitation, and percentage of sunshine. We also sought identical information for shedding events. It was hoped that frequency, synoptic conditions responsible, and the distribution of events throughout New England could be learned. Station personnel were requested to submit their choice of two forms, whichever was most convenient for their particular situation. Section A of Part II requested information for an individual event. An instruction sheet urged operators to complete and return this form following each event if icing was rare at their location. Realizing that some installations frequently suffer heavy and extended icing, we provided an optional Section B which asked instead for a monthly summary of icing and shedding.

The data obtained from Part II were incomplete and unsatisfactory. Although 35 stations indicated in Part I that they would document icing over the ensuing winter, only 15 had sent follow-up information as of 15 May 1985. Nine stations sent a total of 15 Section A reports on individual events. Only three other stations chose to summarize, with a total of five monthly reports (Section B). The three other stations reported at the end of the season that they had experienced no icing. Considering the sparsity of data, we are not confident that all icing events at these stations were documented. We therefore conclude that a voluntary mail survey of this type is not an effective means for obtaining quantitative intensity, frequency, and areal distribution data on atmospheric icing.

A cover letter explaining the scientific purpose of the study was included, but our questionnaire still met with resistance and suspicion on the part of some station managers, leading to reluctance to candidly describe their icing problems. The data obtained should therefore be analyzed with this fact in mind.

Ambiguity in data interpretation is always a problem with a subjective survey. Many of our questions elicited qualitative responses which are not directly comparable between stations. The "degree of icing" response is especially difficult to interpret, as some respondents described icing frequency and severity in general while others tempered their answers by noting the effect icing had on their business operations. For example, a station with highly successful protection and hence few problems may experience severe icing based on frequency and magnitude, whereas another station may often suffer transmission problems from relatively mild icing. However, both might be described by those responding as severe cases. Therefore it is advisable to study all the information provided in Appendix B and Table 2 concerning any particular station before drawing conclusions about its icing degree.

**Data presentation**

Appendix B contains a summary of the information obtained from all stations responding. It lists them alphabetically by state and then by city with the tower location, if different, in parentheses. The name of the person contacted is also given. Elevations in meters above mean sea level (AMSL) of the tower base and the uppermost element of the mast appear in column 2. Column 3 is the respondent's subjective evaluation of the overall degree of his icing-related problems. The next two columns give average annual cost categories for *maintenance* of icing protection equipment and related energy costs and *repairs* to equipment from ice and wind damage. The last column lists specific icing problems experienced or expected, along with subjective evaluations of frequency and severity of each, types of icing protection devices in use, and general comments.

Table 2 provides more detailed information on the mast and its site. The cost entry is a combination of the respondents' average annual costs for maintenance of icing protection equipment and repairs of icing-related damage. To arrive at the cost figure, we assumed the midpoint of the two cost ranges selected by the respondent for questions 7 and 8 in Part 1 of the survey. Summing the two

**Table 2. Details of mast installations of all respondents.**

| *Sta* | *ID* | *Cost* | *Grnd* | *Base* | *Mast* | *Top* | *G* | *RU* | *OP* | *LHM* | *AFT* | *Sea* | *IPD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 125 | 2 | 2 | 91 | 93 | N | R | O | L | A | 4 | None |
| 2 | 1 | 125 | xxxx | xxxx | 104 | xxxx | Y | U | M | H | A | 4 | None |
| 3 | 1 | 250 | 223 | 223 | 81 | 304 | N | R | M | H | AF | 40 | Ht |
| 4 | 3 | 750 | 122 | 122 | 408 | 530 | Y | U | M | H | F | 48 | C |
| 5 | 1 | 125 | 8 | 8 | 47 | 54 | N | U | M | H | A | 4 | None |
| 6 | 1 | 250 | 213 | 213 | 27 | 241 | N | R | O | M | F | 40 | W |
| 7 | 0 | 0 | 46 | 107 | 8 | 114 | N | U | M | H | F | 32 | None |
| 8 | 1 | 250 | 145 | 145 | 12 | 165 | Y | R | O | H | F | 8 | None |
| 9 | 4 | 1125 | 195 | 195 | 277 | 472 | Y | R | P | H | T | 16 | Hi |
| 10 | 2 | 500 | 35 | 35 | 114 | 149 | Y | R | M | H | F | 4 | Hm |
| 11 | 1 | 125 | 160 | 160 | 146 | 306 | Y | R | M | H | T | 24 | Ht+p |
| 12 | 1 | 125 | 160 | 160 | 146 | 306 | Y | R | M | H | F | 24 | None |
| 13 | 1 | 250 | 189 | 189 | 90 | 279 | Y | R | M | L | T | 24 | R,S |
| 14 | 1 | 250 | 49 | 49 | 114 | 163 | N | U | M | H | AF | 4 | Ht |
| 15 | 1 | 125 | 46 | 46 | 124 | 170 | Y | R | M | H | A | 48 | None |
| 16 | 1 | 250 | 377 | 377 | 34 | 411 | Y | R | P | H | F | 129 | Hm |
| 17 | 2 | 500 | 4 | 238 | 8 | 246 | N | U | O | L | F | 4 | Hm |
| 18 | 1 | 125 | 5 | 48 | 60 | 107 | Y | U | O | L | F | 4 | None |
| 19 | 1 | 125 | 117 | 117 | 24 | 142 | Y | R | O | H | F | 97 | None |
| 20 | 1 | 125 | 51 | 61 | 9 | 70 | Y | R | M | H | F | 40 | None |
| 21 | x | xxxx | 263 | 263 | 24 | 287 | Y | R | P | H | F | 153 | None |
| 22 | 3 | 750 | 267 | 267 | 158 | 426 | Y | R | O | M | F | 10 | Hi |
| 23 | 2 | 375 | 110 | 110 | 57 | 167 | Y | U | M | H | A | 105 | None |
| 24 | 1 | 125 | 4 | 4 | 56 | 60 | Y | U | O | H | A | 16 | None |
| 25 | 1 | 125 | 335 | 335 | 47 | 383 | Y | R | O | H | A | 153 | None |
| 26 | 1 | 125 | 76 | 76 | 61 | 137 | Y | U | O | L | A | 161 | None |
| 27 | x | xxxx | 61 | 61 | 123 | 184 | Y | R | M | L | AF | 32 | None |
| 28 | 1 | 250 | xxxx | xxxx | 9 | xxxx | Y | U | M | H | F | 40 | Ht |
| 29 | 2 | 500 | 67 | 67 | 29 | 96 | N | U | M | H | F | 4 | Ht |
| 30 | 5 | 17500 | 37 | 37 | 324 | 361 | N | U | M | H | T | 16 | Hi,R,E |
| 31 | 4 | 6000 | 30 | 30 | 411 | 441 | Y | U | M | L | F | 16 | R,S |
| 32 | 1 | 125 | 68 | 68 | 69 | 137 | Y | R | O | H | A | 24 | None |
| 33 | 2 | 500 | 616 | 616 | 46 | 661 | Y | R | M | M | F | 177 | Hm |
| 34 | 1 | 250 | 193 | 193 | 70 | 263 | Y | R | M | M | F | 129 | R |
| 35 | 1 | 125 | 309 | 309 | 67 | 376 | Y | U | M | L | A | 145 | None |

Key:

Sta = Station alphabetical number from Appendix B.

ID = Icing degree, where:

5 = > $10,000 4 = $1000–9999 3 = $650–999

2 = $350–649 1 = $1–349 0 = zero dollars

Cost = The sum of the midpoints of average annual cost ranges for icing-related repairs and maintenance.

Grnd = Ground elevation at tower location (meters above mean sea level).

Base = Elevation at base of tower (mAMSL).

Mast = Overall height of mast installation (meters).

Top = Elevation at top of mast installation (mAMSL).

Site descriptors:

G = Guyed tower? **Y**es or **N**o or **B**oth types in use.

RU = **R**ural or **U**rban.

OP = **O**pen, **P**rotected, or **M**ixed.

LHM = **L**evel, **H**illy, or **M**ountainous.

AFT = **AM** radio, **FM** radio, or **T**elevision station.

Sea = Approximate distance to ocean (miles).

IPD = Icing protection devices in use, where:

C = surface coating, E = emergency backup antenna in place, R = radome, S = ice shield, W = wide-band antenna in use, H = electric heater, where m = manually activated, i = ice detector activated, t = temperature activated, p = precipitation activated.

**Table 2 (cont'd).**

| *Sta* | *ID* | *Cost* | *Grnd* | *Base* | *Mast* | *Top* | *G* | *RU* | *OP* | *LHM* | *AFT* | *Sea* | *IPD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 1 | 250 | 540 | 540 | 46 | 586 | Y | R | M | M | F | 145 | Ht+p |
| 37 | 3 | 750 | 38 | 38 | 293 | 331 | Y | R | M | L | T | 24 | Ht,R |
| 38 | 0 | 0 | 195 | 195 | 70 | 265 | Y | R | O | L | A | 89 | None |
| 39 | 2 | 375 | 250 | 250 | 46 | 296 | Y | R | O | H | F | 89 | Hm |
| 40 | 3 | 875 | 366 | 366 | 47 | 413 | Y | R | M | M | T | 121 | Hm |
| 41 | 1 | 125 | 22 | 22 | 107 | 129 | N | U | O | L | AF | 97 | None |
| 42 | 3 | 875 | 267 | 267 | 158 | 426 | Y | R | O | M | T | 97 | Hi |
| 43 | 1 | 125 | 67 | 67 | 21 | 88 | Y | R | P | H | F | 40 | None |
| 44 | 1 | 125 | 64 | 64 | 56 | 120 | Y | R | M | L | A | 32 | None |
| 45 | 1 | 250 | 38 | 38 | 366 | 404 | Y | U | M | H | F | 16 | R |
| 46 | 1 | 250 | 335 | 335 | 59 | 394 | N | R | M | H | F | 80 | H |
| 47 | 1 | 125 | 250 | 250 | 116 | 366 | N | R | M | H | A | 72 | None |
| 48 | 0 | 0 | 61 | 61 | 56 | 117 | N | xx | xx | xx | A | 32 | None |
| 49 | 1 | 125 | 48 | 58 | 22 | 80 | Y | U | O | H | F | 48 | None |
| 50 | 1 | 250 | 232 | 232 | 44 | 276 | Y | R | M | H | F | 40 | S |
| 51 | 2 | 375 | 55 | 55 | 123 | 178 | B | U | O | H | A | 48 | None |
| 52 | 1 | 250 | 43 | 43 | 110 | 152 | Y | R | M | H | F | 4 | C |
| 53 | 3 | 750 | 61 | 61 | 85 | 146 | Y | R | M | H | F | 16 | Hm |
| 54 | 2 | 500 | 88 | 88 | 89 | 178 | Y | U | M | H | F | 4 | Ht |
| 55 | 1 | 250 | 114 | 114 | 128 | 242 | Y | R | O | L | AF | 129 | Hm |
| 56 | 3 | 875 | 210 | 210 | 193 | 403 | Y | R | M | H | T | 32 | Hm,R |
| 57 | 1 | 250 | 143 | 143 | 152 | 296 | Y | R | O | H | F | 24 | Ht |
| 58 | 3 | 875 | 1906 | 1906 | 37 | 1943 | Y | R | O | M | T | 113 | R |
| 59 | 5 | 17500 | 375 | 375 | 398 | 773 | Y | R | M | M | T | 40 | Ht,R,S |
| 60 | 1 | 125 | 23 | 23 | 88 | 111 | Y | R | M | L | F | 8 | R |
| 61 | 1 | 125 | 76 | 76 | 142 | 218 | Y | R | O | L | F | 16 | None |
| 62 | 1 | 125 | 15 | 15 | 54 | 69 | Y | R | O | L | A | 16 | None |
| 63 | 0 | 0 | 15 | 15 | 74 | 89 | Y | R | O | L | A | 1 | None |
| 64 | 2 | 375 | 23 | 23 | 69 | 91 | Y | U | O | P | F | 4 | Hm |
| 65 | 2 | 500 | 0 | 0 | 79 | 79 | N | U | M | L | AF | 0 | Ht |
| 66 | 0 | 0 | 283 | 283 | 24 | 308 | Y | R | M | H | F | 72 | R |
| 67 | 1 | 125 | 87 | 87 | 94 | 181 | Y | R | P | L | A | 7 | None |
| 68 | 1 | 125 | 194 | 194 | 30 | 224 | Y | R | P | H | F | 72 | Hm |
| 69 | 1 | 125 | 137 | 137 | 73 | 210 | Y | R | M | M | A | 72 | None |
| 70 | 1 | 125 | 372 | 372 | 24 | 396 | N | R | M | M | F | 72 | None |
| 71 | 1 | 125 | 140 | 140 | 90 | 230 | Y | R | P | L | A | 40 | None |
| 72 | 3 | 875 | 122 | 122 | 152 | 274 | Y | R | M | H | T | 48 | Hm |
| 73 | 1 | 125 | 18 | 18 | 62 | 81 | Y | R | P | H | A | 16 | None |
| 74 | 1 | 250 | 324 | 324 | 49 | 404 | Y | R | P | H | AF | 145 | Hm |
| 75 | 1 | 125 | 146 | 146 | 53 | 200 | Y | U | O | L | A | 121 | None |
| 76 | 1 | 125 | 160 | 160 | 46 | 206 | Y | R | O | L | A | 145 | None |
| 77 | 1 | 125 | 61 | 61 | 114 | 175 | Y | U | M | L | A | 56 | None |
| 78 | 2 | 500 | 390 | 390 | 38 | 428 | Y | R | M | H | F | 64 | Hm |
| 79 | 1 | 125 | 61 | 61 | 91 | 152 | N | U | O | L | A | 56 | None |
| 80 | 1 | 250 | 594 | 594 | 37 | 632 | Y | R | M | M | F | 89 | Hm |
| 81 | 1 | 125 | 171 | 171 | 63 | 234 | Y | R | M | H | A | 56 | None |
| 82 | 1 | 125 | xxxx | 94 | 12 | 107 | Y | R | M | H | F | 16 | None |
| 83 | 1 | 250 | 50 | 50 | 123 | 173 | Y | R | M | H | F | 8 | Ht |
| 84 | 1 | 125 | 46 | 67 | 21 | 89 | N | R | O | H | F | 4 | None |
| 85 | 1 | 125 | 9 | 9 | 98 | 107 | Y | R | O | L | A | 4 | None |
| 86 | 1 | 250 | 73 | 73 | 149 | 223 | N | R | M | H | AF | 8 | Hm+i |
| 87 | 0 | 0 | 3 | 3 | 134 | 137 | Y | xx | xx | xx | A | 4 | None |
| 88 | 1 | 125 | 12 | 12 | 166 | 181 | Y | R | M | H | AF | 4 | W |
| 89 | 2 | 500 | 69 | 69 | 305 | 373 | Y | R | M | H | T | 24 | Ht+p |
| 90 | 1 | 125 | 76 | 76 | 61 | 137 | Y | R | M | L | A | 8 | None |
| 91 | 0 | 0 | 101 | 101 | 46 | 146 | Y | R | P | H | A | 153 | None |

**Table 2 (cont'd). Details of mast installations of all respondents.**

| *Sta* | *ID* | *Cost* | *Grnd* | *Base* | *Mast* | *Top* | *G* | *RU* | *OP* | *LHM* | *AFT* | *Sea* | *IPD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 92 | 0 | 0 | 469 | 469 | 46 | 515 | Y | xx | xx | xx | F | 15 | W |
| 93 | 3 | 750 | 1219 | 1219 | 40 | 1259 | N | R | O | M | T | 225 | Hm,S |
| 94 | 3 | 875 | 1259 | 1259 | 32 | 1291 | N | R | O | M | T | 225 | Hi |
| 95 | 1 | 250 | 87 | 87 | 110 | 197 | Y | xx | xx | xx | F | 257 | Ht |
| 96 | 1 | 125 | 31 | 31 | 90 | 122 | Y | R | O | L | A | 257 | None |
| 97 | 4 | 1500 | 1280 | 1280 | 92 | 1372 | Y | R | O | M | T | 225 | Hi,S |
| 98 | 1 | 125 | 131 | 131 | 37 | 168 | N | R | M | H | F | 257 | None |
| 99 | 1 | 125 | 140 | 151 | 6 | 157 | Y | U | M | L | F | 209 | None |
| 100 | 2 | 500 | 290 | 296 | 26 | 321 | Y | R | M | H | F | 161 | Ht |
| 101 | 1 | 125 | 198 | 198 | 53 | 251 | Y | R | M | H | A | 193 | None |
| 102 | 2 | 500 | 1291 | 1291 | 18 | 1309 | N | R | O | M | F | 185 | Hm+t,R |
| 103 | 1 | 125 | 226 | 226 | 56 | 282 | Y | R | P | H | A | 161 | None |
| 104 | 3 | 875 | 1032 | 1032 | 40 | 1072 | N | R | O | M | T | 161 | Hi |
| 105 | 1 | 250 | 244 | 244 | 91 | 335 | Y | R | O | H | AF | 145 | Hm |
| 106 | 1 | 125 | 134 | 134 | 75 | 209 | Y | R | O | H | A | 145 | None |
| 107 | 1 | 250 | 305 | 305 | 61 | 366 | Y | R | O | M | F | 145 | Hm |
| 108 | 4 | 6000 | 920 | 920 | 49 | 969 | Y | R | O | M | T | 145 | Ht |

midpoints resulted in the single maintenance/repair value shown in column 2. For example, Station 9, as shown in Appendix B, selected the range $250–500 for its annual maintenance costs, the midpoint being $375. Its repair costs range from $500–1000 annually, the midpoint being $750. The sum of these two values, $1125, appears as the cost entry in Table 2. Based on this value, the stations have been categorized in the five levels of icing degree (ID) shown below:

| ID | Cost | No. of stations |
|---|---|---|
| 5 | $10,000 or greater | 2 |
| 4 | $1000–9999 | 4 |
| 3 | $750–999 | 12 |
| 2 | $350–749 | 15 |
| 1 | $1–349 | 74 |
| 0 | 0 or unknown | 11 |

Table 3 lists in decreasing order of severity those stations with annual icing-related costs of $350 or more, meaning that those with ID values of 2 or greater make up our list of stations with moderate and more severe icing.

In all tables, the base elevation differs from ground elevation when a tower is located atop a building. For example, WERS-FM's base elevation on the roof of the Prudential Center in Boston is 238 m, whereas the ground elevation is only 4 m AMSL.

## DISCUSSION

### Survey response distribution

In general, the survey response rate was highest for TV stations, with FM stations slightly higher than AM stations. It might be inferred that the response rate would be higher for those stations with greater sensitivity toward atmospheric icing. Those stations would be inclined to seek solutions and therefore be more interested in participating in the survey. Figure 5 shows the distribution of response percentages on a state-by-state basis and by station type. The states with higher response rates were New Hampshire, Vermont and Rhode Island, and we might conclude that these states experience more icing. New Hampshire and Vermont may be more susceptible due to the higher latitude, higher elevations, mountain proximity, and storm track influences. Rhode Island's high rate may be due to ocean proximity but is more likely due to sample error since only 30 stations were contacted, the lowest number for any state.

We consolidated parameter averages for all respondents based on station type, use of icing protection, and guyed versus non-guyed towers; Table 4 summarizes the information obtained. For example, the average ground elevation of responding AM stations is half of that for FM stations, which is in turn less than half the elevation of TV stations. Mast height in the study for TV stations tends to be more than twice that for AM and FM stations, which were equivalent. The average mast

**Table 3. Stations with moderate and more severe icing grouped by degree of icing.**

| *Rank* | *Sta* | *ID* | *Cost* | *Grnd* | *Base* | *Mast* | *Top* | *G* | *RU* | *OP* | *LHM* | *AFT* | *Sea* | *IPD* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 59 | 5 | 17500 | 375 | 375 | 398 | 773 | Y | R | M | M | T | 40 | Ht,R,S |
| | 30 | 5 | 17500 | 37 | 37 | 324 | 361 | N | U | M | H | T | 16 | Hi,R,E |
| 2 | 108 | 4 | 6000 | 920 | 920 | 49 | 969 | Y | R | O | M | T | 145 | Ht |
| | 31 | 4 | 6000 | 30 | 30 | 411 | 441 | Y | U | M | L | F | 16 | R,S |
| 3 | 97 | 4 | 1500 | 1280 | 1280 | 92 | 1372 | Y | R | O | M | T | 225 | Hi,S |
| 4 | 9 | 4 | 1125 | 195 | 195 | 277 | 472 | Y | R | P | H | T | 16 | Hi |
| 5 | 104 | 3 | 875 | 1032 | 1032 | 40 | 1072 | N | R | O | M | T | 161 | Hi |
| | 94 | 3 | 875 | 1259 | 1259 | 32 | 1291 | N | R | O | M | T | 225 | Hi |
| | 72 | 3 | 875 | 122 | 122 | 152 | 274 | Y | R | M | H | T | 48 | Hm |
| | 58 | 3 | 875 | 1906 | 1906 | 37 | 1943 | Y | R | O | M | T | 113 | R |
| | 56 | 3 | 875 | 210 | 210 | 193 | 403 | Y | R | M | H | T | 32 | Hm,R |
| | 42 | 3 | 875 | 267 | 267 | 158 | 426 | Y | R | O | M | T | 97 | Hi |
| | 40 | 3 | 875 | 366 | 366 | 47 | 413 | Y | R | M | M | T | 121 | Hm |
| 6 | 93 | 3 | 750 | 1219 | 1219 | 40 | 1259 | N | R | O | M | T | 225 | Hm,S |
| | 53 | 3 | 750 | 61 | 61 | 85 | 146 | Y | R | M | H | F | 16 | Hm |
| | 37 | 3 | 750 | 38 | 38 | 293 | 331 | Y | R | M | L | T | 24 | Ht,R |
| | 22 | 3 | 750 | 267 | 267 | 158 | 426 | Y | R | O | M | F | 10 | Hi |
| | 4 | 3 | 750 | 122 | 122 | 408 | 530 | Y | U | M | H | F | 48 | C |
| 7 | 102 | 2 | 500 | 1291 | 1291 | 18 | 1309 | N | R | O | M | F | 185 | Hm+t,R |
| | 100 | 2 | 500 | 290 | 296 | 26 | 321 | Y | R | M | H | F | 161 | Ht |
| | 89 | 2 | 500 | 69 | 69 | 305 | 373 | Y | R | M | H | T | 24 | Ht+p |
| | 78 | 2 | 500 | 390 | 390 | 38 | 428 | Y | R | M | H | F | 64 | Hm |
| | 65 | 2 | 500 | 0 | 0 | 79 | 79 | N | U | M | L | AF | 0 | Ht |
| | 54 | 2 | 500 | 88 | 88 | 89 | 178 | Y | U | M | H | F | 4 | Ht |
| | 33 | 2 | 500 | 616 | 616 | 46 | 661 | Y | R | M | M | F | 177 | Hm |
| | 29 | 2 | 500 | 67 | 67 | 29 | 96 | N | U | M | H | F | 4 | Ht |
| | 17 | 2 | 500 | 4 | 238 | 8 | 246 | N | U | O | L | F | 4 | Hm |
| | 10 | 2 | 500 | 35 | 35 | 114 | 149 | Y | R | M | H | F | 4 | Hm |
| 8 | 64 | 2 | 375 | 23 | 23 | 69 | 91 | Y | U | O | P | F | 4 | Hm |
| | 51 | 2 | 375 | 55 | 55 | 123 | 178 | B | U | O | H | A | 48 | None |
| | 39 | 2 | 375 | 250 | 250 | 46 | 296 | Y | R | O | H | F | 89 | Hm |
| | 23 | 2 | 375 | 110 | 110 | 57 | 167 | Y | U | M | H | A | 105 | None |

Key:

Sta = Station alphabetical number from Appendix B.
ID = Icing degree, where:
5 = > \$10,000 4 = \$1000–9999 3 = \$650–999
2 = \$350–649 1 = \$1–349 0 = zero dollars
Cost = The sum of the midpoints of average annual cost ranges for icing-related repairs and maintenance.
Grnd = Ground elevation at tower location (meters above mean sea level).
Base = Elevation at base of tower (mAMSL).
Mast = Overall height of mast instasllation (meters).
Top = Elevation at top of mast installation (mAMSL).

Site descriptors:
G = Guyed tower? **Y**es or **N**o or **B**oth types in use.
RU = **R**ural or **U**rban.
OP = **O**pen, **P**rotected, or **M**ixed.
LHM = **L**evel, **H**illy, or **M**ountainous.
AFT = **AM** radio, **FM** radio, or **T**elevision station.
Sea = Approximate distance to ocean (miles).
IPD = Icing protection devices in use, where:
C = surface coating, E = emergency backup antenna in place, R = radome, S = ice shield,
W = wide-band antenna in use, H = electric heater, where m = manually activated, i = ice detector activated, t = temperature activated, p = precipitation activated.

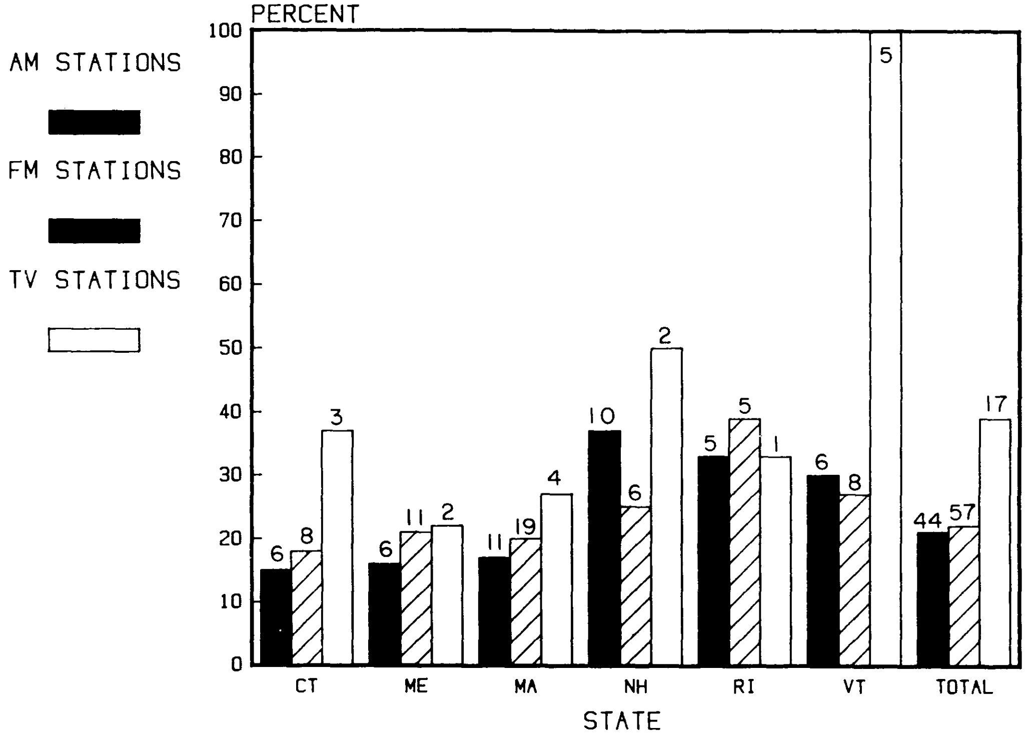


*Figure 5. Station response to survey (state-by-state percentages). Numbers at top of columns represent total number of stations.*

top elevations for AM, FM and TV-only stations are 178, 295 and 724 m AMSL respectively. In terms of average distance to the ocean, AM and FM masts were nearly equidistant at 72 and 66 km respectively, whereas TV masts averaged 92 km. Figure 6 shows the average annual costs for icing-related repairs and maintenance based on station type. It can be seen that by far the higher costs are incurred by television stations at over $3000 per year. AM stations expend an average of only $121 per year while the cost to FM stations is more than three times greater at $402 per year. The higher costs to FM and TV broadcasters may be partly attributable to their higher average elevations and mast heights. Distance to the ocean seems to be inversely related to degree of icing, as TV stations with high cost are on average further from the coast.

**Effect of icing protection on parameter averages**

Another indication of icing degree is the distribution of stations that use icing protection devices. Fifty-seven, or 48% of the total 118 stations, use some form of protection, and 77% of those employ the active method of electrically heating transmission elements. The remaining 23% use the passive methods of radomes, polymer coatings, shields, or wide-band antennas. Shown below is the per-state breakdown of stations using some form of icing protection, the total number reporting, and the percentage of the total.

| Conn. | Maine | Mass. | N.H. | R.I. | Vt. |
|---|---|---|---|---|---|
| 8/19 | 12/21 | 16/34 | 6/19 | 4/13 | 11/20 |
| (42%) | (57%) | (47%) | (32%) | (31%) | (55%) |

The higher latitude states of Maine and Vermont are the highest percentage users. The exception is New Hampshire, which is inexplicably low based on our overall latitude and elevation assumptions. Comparisons of the various parameters between stations with and without IPDs are shown in Table 4b. Two facts are immediately obvious. None of the 34 AM stations in the study use IPDs, whereas all 17 TV stations use some form of protection. This can be interpreted to mean that AM transmission is nearly insensitive to expected New England icing levels, and operators in general do not consider icing a problem for this type of broadcast. Conversely, TV transmission is highly sensitive to

**Table 4. Parameter averages.**

| Station type | No. of stations | Cost (dollars) | Grnd (mAMSL) | Base (mAMSL) | Mast (m) | Top (mAMSL) | Sea (km) |
|---|---|---|---|---|---|---|---|
| **a. By station type** | | | | | | | |
| All stations* | 118 | 689 | 214 | 216 | 93 | 312 | 71 |
| AM-only stations | 34 | 121 | 102 | 102 | 76 | 178 | 72 |
| All stations w/AM† | 44 | 148 | 105 | 105 | 83 | 189 | 69 |
| FM-only stations | 47 | 402 | 207 | 213 | 76 | 295 | 66 |
| All stations w/FM† | 57 | 377 | 190 | 195 | 81 | 282 | 64 |
| TV stations only | 17 | 3066 | 567 | 567 | 157 | 724 | 92 |
| **b. Parameter averages of stations with or without icing protection devices** | | | | | | | |
| All stations with | 57 | 1246 | 327 | 332 | 114 | 448 | 72 |
| All stations without | 53 | 113 | 102 | 105 | 68 | 174 | 70 |
| AM stations with | 0 | — | — | — | — | — | — |
| AM stations without | 34 | 121 | 102 | 102 | 76 | 178 | 72 |
| FM stations with | 40 | 472 | 223 | 229 | 96 | 328 | 64 |
| FM stations without | 17 | 125 | 109 | 118 | 47 | 169 | 68 |
| TV stations with | 17 | 3066 | 567 | 567 | 157 | 724 | 92 |
| TV stations without | 0 | — | — | — | — | — | — |
| **c. Parameter averages of stations with guyed or non-guyed towers** | | | | | | | |
| All stations guyed | 90 | 609 | 200 | 200 | 98 | 303 | 72 |
| All stations nonguyed | 29 | 897 | 249 | 260 | 78 | 338 | 63 |
| AM stations guyed | 34 | 136 | 113 | 113 | 80 | 195 | 80 |
| AM stations nonguyed | 11 | 205 | 73 | 73 | 96 | 104 | 34 |
| FM stations guyed | 43 | 415 | 185 | 184 | 90 | 282 | 68 |
| FM stations nonguyed | 14 | 268 | 205 | 227 | 54 | 282 | 60 |
| TV stations guyed | 13 | 2471 | 469 | 469 | 172 | 641 | 72 |
| TV stations nonguyed | 4 | 5000 | 887 | 887 | 109 | 996 | 158 |

* Combination AM-FM stations are double-counted.
† Includes 10 combination AM-FM stations.

icing, and icing protection is costly, averaging over $3000 per year per station. Figure 7 illustrates the large difference in icing costs for the three station types, depending on whether or not IPDs are used. Since the usage of IPDs was clearly specific according to broadcast type, we chose to look only at the distribution of protected FM stations; Figure 8 shows state-by-state percentages. Admittedly, the sample size is small, but this graph does in fact show the higher latitude states of Maine, Vermont and New Hampshire as high-percentage users. New Hampshire's percentage is increased when the 10 AM stations are factored out of the total of 19 reporting. The evidence that the mountainous northern states are more subject to icing is strengthened. Table 4b also illustrates the relationship of IPD usage with respect to ground elevation and mast height. The average ground elevation of FM stations *with* protection is 223 m AMSL, or roughly twice that of FM stations *without* IPDs. The elevation of FM stations without protection is equivalent to that of AM stations, at 102 m AMSL. Taller masts (average 96 m) are in use at FM stations with IPDs than at stations without them (average 47 m). This lends credence to the assumption that icing severity is dependent upon elevation above sea level and mast height above local ground elevation. The average distance to the ocean for FM stations with and without IPDs is virtually the same, indicating that in New England ocean proximity has little to do with the need for protection.

### Effect of tower type on parameter averages

Parameter averages were tabulated for the respondents based on the use of guyed versus nonguyed towers (Table 4c). Over 75% of all reporting stations use guyed towers. It was initially thought that guyed towers might have a higher maintenance/repair cost-average due to a larger ice-fall zone about the tower base. Icing would oc-

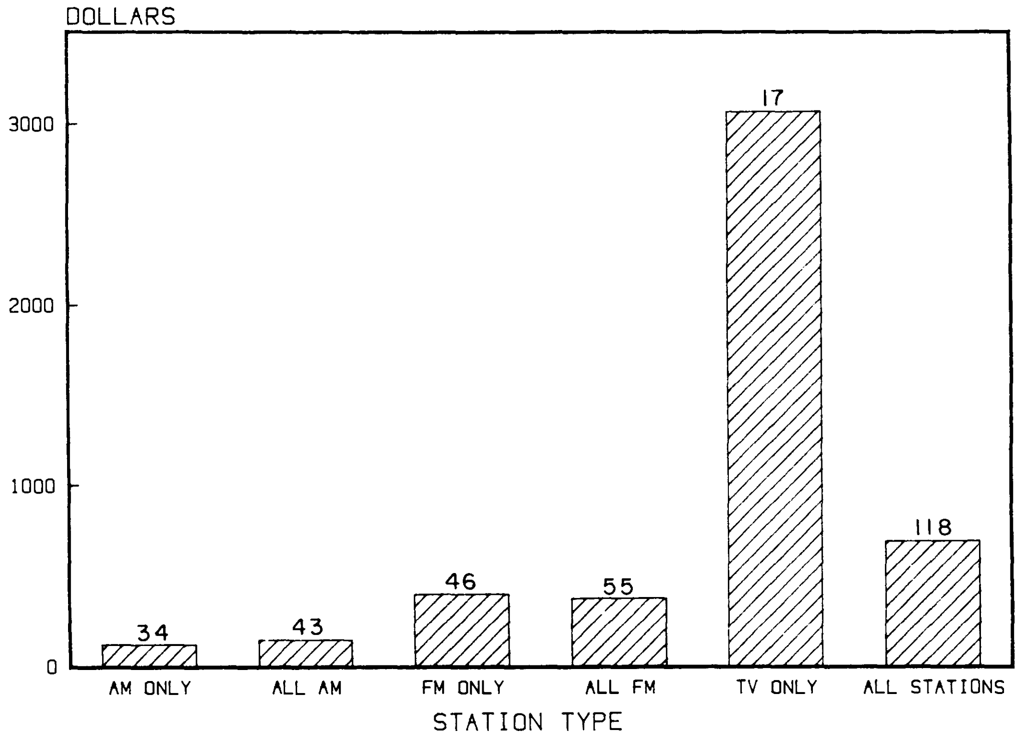


*Figure 6. Icing-related station costs (average cost per year). Numbers at top of columns represent total number of stations.*

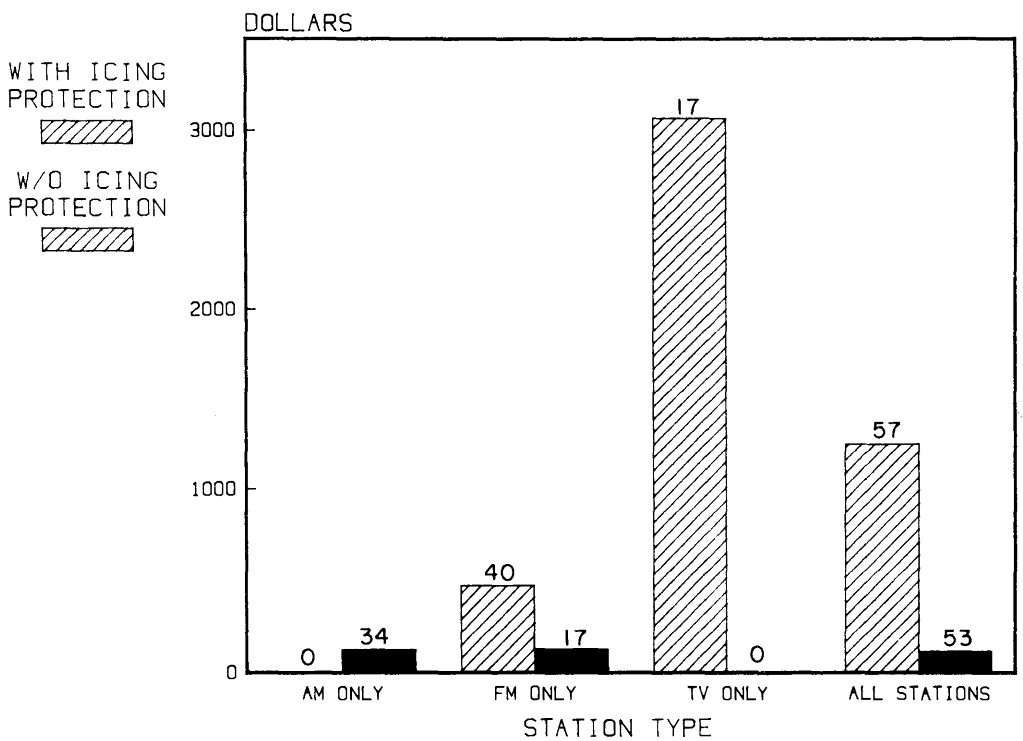


*Figure 7. Icing-related station costs (with and without icing protection). Numbers at top of columns represent total number of stations.*

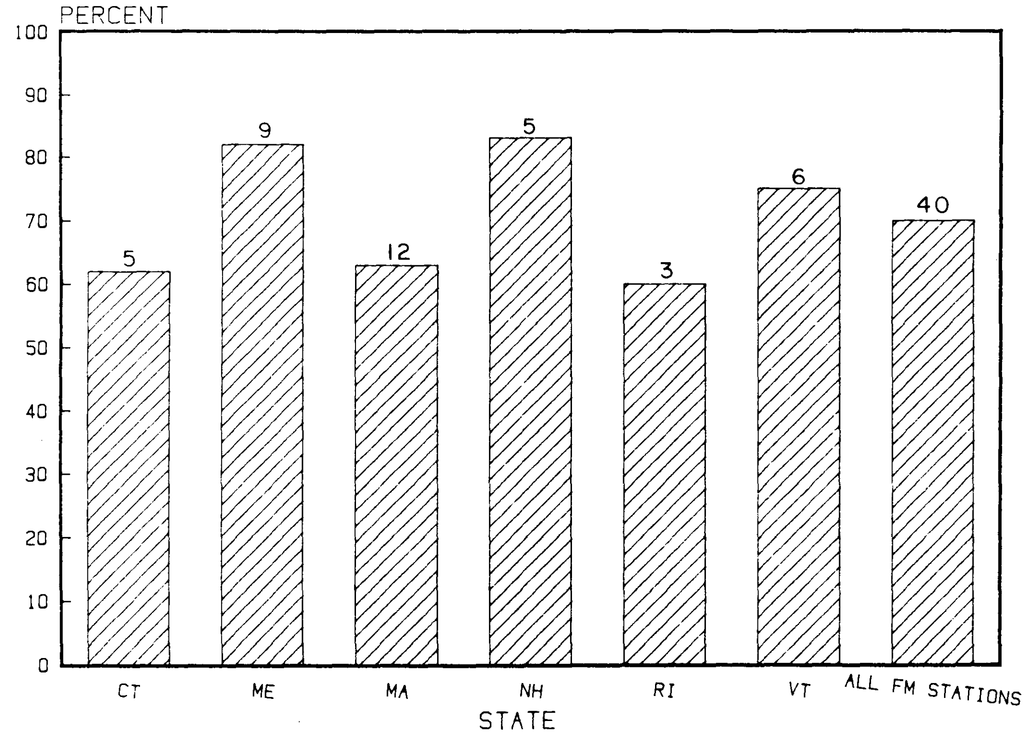


*Figure 8. Icing protection (state-by-state percentages, FM stations only). Numbers at top of columns represent total number of stations.*

cur not only on the tower, but also on the guy cables, which would increase the possibility of ice falling onto adjacent property. For urban facilities this could be the source of higher associated costs. As the data show, it is difficult to make conclusions about costs based on the use of guyed or non-guyed towers alone. The cost averages are plotted in Figure 9 according to station type. A large difference is evident between guyed and non-guyed TV stations: $2471 and $5000 per year respectively. Non-guyed TV towers are more than twice as expensive to maintain as those that are guyed. In this case, the first appearance is misleading since the sample of non-guyed TV towers consists of only four stations and one of these is WNEV in Newton, Massachusetts. Its average yearly cost is $17,500, which highly exaggerates the averages for the other three stations. WNEV has a 324-m-high mast in a heavily developed area, and even though ice-falls are infrequent the resulting damage to adjacent property is sometimes very high. The other three stations have short towers, on the average of 37 m high, and are located on mountaintops where ice falling from guy cables has no economic impact. Disregarding station WNEV, average cost for non-guyed TV stations is only $833 per year.

Average mast heights for guyed and non-guyed AM towers and guyed FM towers are all nearly the same (80, 96 and 90 m respectively). Yet non-guyed FM towers average only 54 m high. Yearly cost in this case parallels mast height. Non-guyed AM towers are taller and cost more to maintain than guyed AM towers. Conversely, for FM towers, the non-guyed type are shorter and cost less per year than those with guy systems. It is interesting to note that the top elevations for both types of FM towers are identical at 282 m AMSL.

The cost averages for urban towers only are equally inexplicable regarding the presence (16 stations) or absence (9 stations) of guy cables. Disregarding two high-cost stations with outlying values (WNEV-TV and WCSH-TV), costs for guyed and non-guyed towers were nearly identical at $242 and $266 per year respectively. Even though the average mast height and ground elevation of guyed urban towers were higher than those of non-guyed urban towers, icing costs were slightly lower. From the information available, it must be concluded that tower type alone is not a good pre-

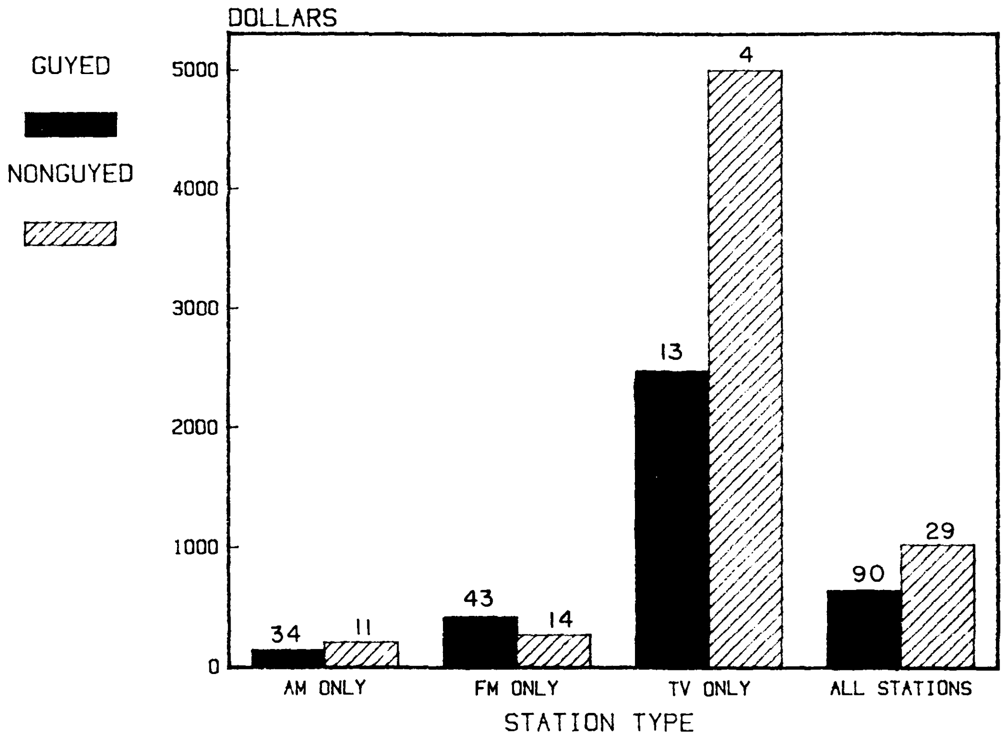


*Figure 9. Icing-related station costs (guyed versus non-guyed towers). Numbers at top of columns represent total number of stations.*

dictor of icing costs and that elevation, exposure, and mast height are more influential factors.

**Moderate and more severe icing locations**

Table 3 lists stations judged to have moderate-to-severe icing; their locations are shown in Figure 10. The table contains just 2 AM-only stations out of the total of 32, and these are the only stations in Table 3 that do not use icing protection. The remaining 30 stations use IPDs of some type, and 26 of these use electrical antenna heaters. Fifteen of the 17 TV stations in the study appear in Table 3, and 14 have ID values of 3 or greater. Another 15 stations in Table 3 are FM broadcasters with an average $900 per year in icing costs.

One might expect the summit of Mt. Washington to have the greatest icing severity due to its elevation, exposure and fierce weather conditions. Personnel at WMTW-TV (station 58) there report that icing occurs during 8–9 months of the year. It is interesting that WMTW's maintenance/repair costs tie it with seven other stations in fifth place on our list, lower than was expected. They do not use conventional antenna heaters but instead successfully employ radomes, short towers, and manual deicing techniques. Their station-to-transmitter microwave dishes are housed inside a large chamber attached to the transmitter building that is heated with the waste heat of a diesel power generator. The exterior wall is fiberglass which infrequently requires manual deicing. Given the severe environment of Mt. Washington, WMTW has remarkable control over their icing-related maintenance and repair costs, which average only about $875 per year.

Portland, Maine's WCSH-TV (station 59) topped the list, having both severe icing conditions and high maintenance/repair costs. They have the tallest mast of all the responding mountaintop installations. Their annual cost for maintenance of protective equipment is reportedly $5,000–10,000, with annual damage expenses (due mainly to falling ice) of over $10,000. A severe buildup of rime and glaze in March 1983 toppled their 400-m mast, causing approximately $34,000 in damages and days of lost airtime before a temporary, less powerful system could be put on-line. It was many months before a new tower was erected and operations returned to normal. The tremendous size of their tower, its high base elevation, and its northerly location are factors contributing to their severe icing problems.

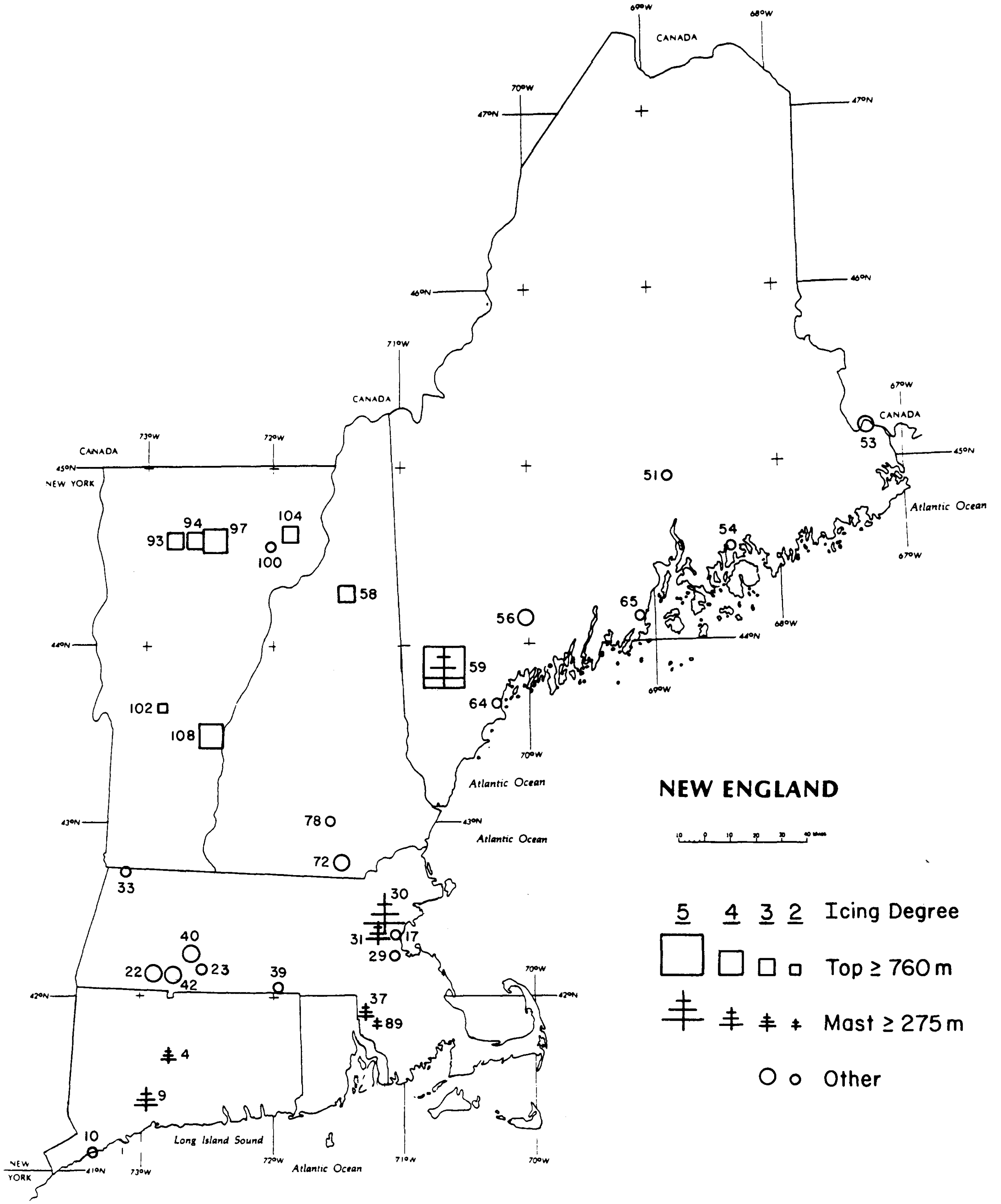


*Figure 10. Tower locations of stations with moderate and more severe icing, showing those with mast heights greater than 275 m and top elevations exceeding 760 m above sea level.*

Two other stations that were top-ranked in icing severity are located within 0.3 km of each other in Newton, Massachusetts. WNEV (station 30) owns a massive self-supported TV tower, whereas WZOU's FM tower (station 31) is guyed. Both stand over 300 m high. As they are situated in an urban area, their costs stem mainly from serious falling ice damage to surrounding property. It should be mentioned that information received from these two stations is more extensive, as their owners were particularly interested in the study. WNEV-TV has installed instrumentation on their tower to record both icing and shedding events in progress. The data obtained from meteorological sensors and video equipment mounted at multiple levels will be made available to us for analysis as the icing season progresses. It is hoped that the data will lead to better understanding of synoptic conditions and the physical processes involved. Detailed records of ice-fall incidents and resulting damage were made available for this study for the entire 28-year history of the WZOU tower (Hurd and Frank 1985). From the 1957–58 winter through 1983–84 (27 years), 16 ice-falls from their tower were significant enough to report. An undetermined number of minor ice-falls went unrecorded, but from the information available, the frequency of 16 "significant" ice-falls in 27 years yields a mean of one every 1.7 years. The actual interval between events was highly erratic, ranging from two weeks to one period of over five years (std dev = 1.6 years). Of the 16 incidents, 8 resulted in damage to tower equipment or surrounding property and 1 involved minor bodily injury (mean frequency of damaging events = 3.0 years, std dev = 2.6 years). Broken windows, dented vehicles, damaged transmission equipment and punctured roofs were most typically reported.

**Relationship of climate, geography and topography to icing severity**

Prior to our survey, we believed that there might be a strong correlation between degree of icing and proximity to the ocean. We reasoned that the liquid water content of the air and the frequency of fogs would be higher and thus cause more icing events. Published maps based on frequency studies of meteorological data (AAF Weather Service 1943, Bennett 1959, McKay and Thompson 1969, and Tattelman and Gringorten 1973) have suggested a relationship between frozen precipitation and coastal proximity. Although the data are inconclusive, the maps indicate that, for the Canadian Maritimes, the influence is toward higher icing frequency, due perhaps to the prevalence of colder air masses. Coastal New England, however, being lower in latitude, appears to be affected in an opposite way, with the latent heat of the ocean perhaps lowering the frequency of icing. Of a total of 17 stations in our study located less than 5 km from the coast, only 6 appear in Table 3. Even those appear low on the list in order of severity; none have an ID number greater than 2. Indeed, all 11 stations within 5 km of the ocean that use IPDs are FM stations, and even though 9 of these stations use antenna deicers, their yearly icing costs average only $341. The cost average for all FM stations with IPDs is $472. Five AM-only stations within 5 km of the coast responded to the survey. Their average yearly costs were only $75 as compared to $121 for all AM-only stations. No TV stations closer than 16 km to the coast, with one exception, responded to our survey, so we are not able to make any statements about ocean influence on this type of broadcast. Our data therefore lend support to the contention that atmospheric icing is moderated by ocean proximity in New England.

Mast height and top elevation appear to be two factors contributing to icing severity. Of the 18 stations with severity values of 3 or greater, 13 have either a mast height greater than 275 m or a top elevation exceeding 760 m AMSL. All six with ID values of 4 or greater have one or the other characteristic, and top-ranked WCSH-TV (station 59) has both. Interestingly, all eight stations in the study with top elevations over 760 m AMSL, and all but one of the eight stations with mast heights in excess of 275 m, appear in Table 3, generally with an ID value of 3 or greater. The only study case not following this trend was WCRB-FM, located in Newton, Massachusetts, less than 1.5 km from previously mentioned WNEV and WZOU. Since they rent space on WBZ-TV's 366-m-tall structure, WCRB is accountable only for icing costs incurred by their own equipment on the tower. Though WBZ-TV declined to participate in this study, they indicated in the preliminary investigation that they commonly experience icing. But with antenna deicers, ice shields, and a concrete transmitter building roof, extraordinary ice-fall damage is not a problem. Aerial photographs show that WBZ's tower is located in an undeveloped, forested area. They are thereby protected from large damage claims by surrounding property owners, which plague WNEV and WZOU.

Not unexpectedly, mountaintop installations dominated the ranks of stations with higher icing costs. The 13 most severely affected stations (icing costs \$875/yr and greater) are an average of 90 km from the ocean at a mean ground elevation of 615 m AMSL. Three of the top six stations are about 16 km from the coast but all three have mast heights of at least 360 m, which more likely is the cause of their icing-related costs. Ten of 18 stations with severity values of 3 or more are located in mountainous terrain where orographic contribution to precipitation and icing is considerable.

We used least-squares regression analysis to test the correlations of icing-related maintenance/repair costs with ground elevation, mast height, distance to the ocean, etc. for all stations surveyed. We believe that due to the ambiguity and subjectivity in our cost categories, we found poor correlation using simple monopolynomial regression. The best simple relationship was cost versus mast height, with a correlation coefficient of $R = 0.542$. Costs versus distance to ocean showed an especially poor trend ($R = 0.137$). Multiple regression of top elevation and mast height together yielded the best correlation with costs. Least-squares bipolynomial equations of:

1. $\text{Costs} = a + bx + cy$ (simple)

2. $\text{Costs} = a + bx + cy + dx^2 + exy + fy^2$ (quadratic)

3. $\text{Costs} = a + bx + cy + dx^2 + exy + fy^2 + gx^3 + hx^2y + ixy^2 + jy^3$ (cubic)

where $x$ = mast height, $y$ = top elevation and $a$–$j$ = coefficients, were generated from the two data sets of all survey respondents and then the 32 stations with moderate and more severe icing. The correlation measures for the bipolynomials are:

| | Simple | Quadratic | Cubic |
|---|---|---|---|
| All respondents | 0.551 | 0.664 | 0.721 |
| Moderate and more severe icing cases | 0.564 | 0.643 | 0.725 |

Three-parameter multiple regression, adding "distance to ocean," produced less favorable correlations. The fact that, at best, only 53% of the variation in our data is explained by the cubic bipolynomial ($R^2 = 0.725^2 = 0.53$) suggests either ambiguity and immeasurable subjectivity in our data or a dependence on other information that we did not obtain. These factors could be related to microclimatic influences or undocumented structural design variations as two possibilities. However, it does appear that there is some correlation between icing costs and the variables of top elevation and mast height. As the ground elevation and the height of the mast above the ground increase, icing becomes more severe and related costs become greater. A warning signal for designers in this region is the fact that 15 out of 16 existing stations in our study having top elevations exceeding 760 m, or mast heights greater than 275 m, all reported moderate or more severe icing.

**Total annual costs**

The damage and maintenance cost ranges in Appendix B for all stations were totaled and are shown below:

| | |
|---|---|
| Annual cost of icing protection maintenance | \$19,000– 52,000 |
| Annual icing damage estimate | \$34,000– 61,000 |
| Total annual icing-related costs | \$53,000–113,000 |

Since the figures are for a survey return of 25% for New England alone, and since many participants undoubtedly tempered the seriousness of their problems, tower icing is clearly a problem of considerable economic importance. At least three TV towers in Maine (WCSH, WVII and WABI) and one on Mt. Greylock in Massachusetts (WCDC) have collapsed due to icing just since 1983. In our estimates of annual costs, we have not included tower replacement costs or revenue losses during replacement periods. The total 1983 damages for the WCDC accident alone were estimated to be \$500,000.

## CONCLUSIONS

High towers on mountaintops are most likely to experience atmospheric icing and associated problems. Costs are higher on average for the northern states of Maine, New Hampshire and Vermont. However, ocean proximity for all New England seems to result in lower annual costs. To protect the quality and dependability of their broadcasts, owners of high-risk installations must employ protection measures. Forty-eight percent of all stations surveyed use some type of icing protection. Deicing of antenna elements and safeguarding against falling ice is a necessity for TV and the majority of FM transmitters. With the current technology, deicing is most often accomplished by activating resistance heating methods in advance of the icing event. Seventy-seven percent of protected stations use electric antenna deicers. AM transmission facilities are not as sensitive to atmospheric icing, although falling ice still must be considered as a potential cost of operation. Costs due to icing appear to increase with the tower's height and overall top elevation, and decrease with ocean proximity. With one exception, all stations with at least 275 m mast heights and/or top elevations in excess of 760 m AMSL reported at least moderate icing. According to our data, icing costs were not related to the use of guyed or non-guyed towers, as other factors were influential and produced contradictory results in analyzing tower type. Total expenditures for maintenance of icing protection systems and damage repairs for our 25% sampling of New England stations were between $53,000 and $113,000 annually, discounting tower replacement costs and revenue losses during replacement periods.

Icing is an important consideration for designers, owners, and engineers. Local climatological records for tower sites can be a valuable tool if carefully studied to determine expected frequency and severity of icing. Based on these data and the type of broadcasting equipment in use or to be installed, protective measures can be better evaluated for their cost effectiveness.

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## APPENDIX A: TOWER ICING SURVEY

### TOWER ICING SURVEY - PART 1

Date ____________

Station name/channel ______________________________________________
Address ___________________________________
___________________________________

Telephone number ____________________

Station engineer or person completing questionnaire ____________________

A. Tower and Location Data

1. Tower manufacturer ____________________________________________
2. Tower model ____________________________________________
3. Year installed ____________
4. Check one: ___ Self-supporting ___ Guyed
5. Brief description of tower design: ___________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

6. Do you presently have any weather sensing equipment in place on/at the tower ? _____

7. List all attached apparatus and their approximate location on the tower (ie antennae,anemometer,STL cables,dishes.etc.):
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

8a. Ground elevation at tower base: ___________
b. Height of tower: ___________
c. Total height of tower plus antennae: ___________

9. List all icing-protection devices now in use(ie radomes,deicers, surface coatings,shields,etc.) and how they are activated (ie manally,temperature-, load-controlled, etc) : ____________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

10. The terrain about the tower is:
a. ___ rural ___ urban

b. ___ totally open ___ totally protected/forested ___ mixed

c. ___ level ___ hilly ___ mountainous

B. General Icing History

1. Do you consider your icing related problems to be:
   ___ insignificant
   ___ less than serious
   ___ moderately serious
   ___ severe

2. Do you consider your wind-related problems to be:
   ___ insignificant
   ___ less than serious
   ___ moderately serious
   ___ severe

3. Please check the appropriate boxes for each of the following wind/ ice problems you experience along with the frequency and severity of each:

| | Never | Sometimes | Often | | Less than serious | Moderately serious | Severe |
|---|---|---|---|---|---|---|---|
| a. | ___ | ___ | ___ | Diminished transmission signal | ___ | ___ | ___ |
| b. | ___ | ___ | ___ | Stretched or frayed guys | ___ | ___ | ___ |
| c. | ___ | ___ | ___ | Broken guys | ___ | ___ | ___ |
| d. | ___ | ___ | ___ | Wind damage to equipment | ___ | ___ | ___ |
| e. | ___ | ___ | ___ | Falling ice damage to tower and equipment | ___ | ___ | ___ |
| f. | ___ | ___ | ___ | Falling ice damage to surrounding property | ___ | ___ | ___ |
| g. | ___ | ___ | ___ | Total broadcast outage | ___ | ___ | ___ |

4a. We have experienced complete tower collapse:
   ___ never   ___ once   ___ more than once

b. which was caused by:
   ___ icing   ___ wind   ___ neither   ___ both

5. If you do not consider icing to be a problem, which statement is most descriptive of your situation?
   ___ Weather and/or location prevent ice accumulation/damage.
   ___ Protective devices are adequate in preventing ice accumulation/damage.

6. For your station :
a. What dollar amount of icing damage would your consider major? _____

b. How often do these major events occur ?
   ___ never   ___ times per year   once every ___ years

7. Our average annual cost for wind/ice damage repairs is:

- ___ 0 to $250
- ___ 250 to $500
- ___ 500 to $1000
- ___ 1000 to $5000
- ___ 5000 to $10,000
- ___ > $10,000

8. Our average annual cost for maintaining icing protective equipment is:

- ___ 0 to $250
- ___ 250 to $500
- ___ 500 to $1000
- ___ 1000 to $5000
- ___ 5000 to $10,000
- ___ > $10,000

9. Our dollar cost for lost air time is $__________ per min/hr/day.

10. We are/are not interested in participating in the second part of the survey to document individual icing events during the coming winter season.

11. Comments/Questions ______________________________________________

______________________________________________________________

______________________________________________________________

Please return completed questionnaire to :

Nathan Mulherin
Snow and Ice Branch
Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755

Thank you.

## TOWER ICING SURVEY - PART 2

INSTRUCTIONS: This part of the survey is to be used to provide detailed information on the icing events as they occur this winter (1984-85).

We would like information on all incidences of transmitter tower icing.

USE A PHOTOCOPY of this questionnaire to file your reports.

We realize that many stations receiving this survey deal with icing constantly throughout the winter so we ask instead that you summarize your situation on a monthly basis using Section B. In addition to the monthly summary however, each damaging or disruptive event should be reported separately using Section A of Part 2.

Please return each report as it is completed to:


Nathan Mulherin
Snow and Ice Branch
Cold Regions Research and
Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755


If you have experienced no incidences that you would consider reportable by May 15th (1985), please mark the space below and return this page only.

____ no icing experienced this year

Today's date ____________

Station name/channel ______________________________
Address ______________________________
______________________________

TOWER ICING SURVEY - PART 2

Station name/channel ________________
Address ________________
________________

SECTION A :

Person completing questionnaire ____________
Today's date ______________

1. Time of icing:
 a. icing began _______ (date)
 b. icing ended _______ (date)

2a. Type of ice (check all that were present and circle that which was most abundant) :
 ___ soft rime(breaks easily) ___ hard rime(smoother,denser)
 ___ clear glaze

 b. Did the ice build up uniformly? _____ (yes/no)
 c. How thick ? ______________

3. Please provide the following information (if available or your best estimate) of the conditions at ground elevation immediately preceeding ice formation on the tower :

| | measured | estimate |
|---|---|---|
| temperature | ______ | ______ |
| windspeed | ______ | ______ |
| wind direction | ______ | ______ |
| humidity | ______ | ______ |
| precipitation | ______ | ______ |

4. If falling ice occurred, please answer the following :
 a. Date when shedding began ____________
 b. Date when shedding ended ____________

 c. The pieces that fell ranged in size from __________ to __________ .

 d. I believe the icefall was caused by :
 ___ wind ___ warm weather ___ both ___ other (__________)

 e. Please provide the following information (if available or your best estimate) of the conditions at ground elevation immediately preceeding the icefall from the tower :

| | measured | estimate |
|---|---|---|
| temperature | ______ | ______ |
| windspeed | ______ | ______ |
| wind direction | ______ | ______ |
| humidity | ______ | ______ |
| precipitation | ______ | ______ |
| percent sunshine | ______ | ______ |

5. If damage or disruption occurred as a result of icing (ie falling ice damage, structural stress, signal interference, etc.),
 a. describe the problem(s) ________________________________________
 ________________________________________________________________

 b. Dollar cost estimate of damage _________ .
 c. Lost broadcast time _________ (mins/hrs/days) .

ALTERNATE REPORT

TOWER ICING SURVEY - PART 2

Station name/channel ____________________
Address ____________________
____________________

SECTION B :

Person completing questionnaire______________

SUMMARY FOR THE MONTH OF ________________

1. Number of days with each type of ice and the thickness range :

____ Soft rime ____________ to ____________ thick

____ Hard rime ____________ to ____________ thick

____ Clear glaze ____________ to ____________ thick

2. Number of days during which ice fell from the tower : ________ .

3. Give percentage of days you believe that the icefall was caused by :

____ Wind

____ Sun

____ Warm weather (cloudy)

____ Combination of two of the above conditions

____ Other (____________________________________)

4. The pieces that fell from the tower ranged in size from

____________ to ____________ (soft rime)

____________ to ____________ (hard rime)

____________ to ____________ (clear glaze)

| Station:Offices<br>(Mast location, if different)<br>Respondent | Transmitter Elevation [1] | Icing Degree [2] | Maintenance [3] | Repairs [4] | Specific Problems, Frequency [5] and Degree [2] | | |
|---|---|---|---|---|---|---|---|
| Connecticut | | | | | | | |
| 1. WICC-AM: Bridgeport<br>L. Ludovici | B = 2<br>91<br>T = 93 | M | 0 | 1 | Wind damage to equipment | S | L |
| | | | | | Falling ice damage to equipment | S | M |
| 2. WNAB-AM: Bridgeport<br>R. Pieger | -<br>104<br>- | L | 0 | 1 | Stretched or frayed guys | S | L |
| | | | | | Icing not a problem - no protective devices in use | | |
| 3. WLAD-AM/WDAQ-FM: Danbury<br>R. Cehak | 223<br>81<br>304 | I | 1 | 1 | Protective devices prevent most problems (temp-activated FM antenna heaters) | | |
| 4. WRCH-FM: Farmington<br>T. Ray | 122<br>408<br>530 | M | 2 | 2 | Diminshed signal | S | M |
| | | | | | Falling ice damage to equipment | S | M |
| | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | Polymer surface coating on FM antenna elements | | |
| 5. WGCH-AM: Greenwich<br>F. Haidu | 8<br>47<br>54 | L | 0 | -- | Diminished signal | S | S |
| | | | | | Falling ice damage to equipment | S | L |
| | | | | | Falling ice damage to surrounding property | S | M |

1 - Elevations given inmetersabove mean sea level: B = elevation at base of tower, T = elevation at top of uppermost element on tower.
2 - Degree of icing is an overall subjective evaluation by individual responding to questionnaire: I - insignificant, L = less than serious, M = moderately serious, S - serious.
3 - Average cost per year for maintenance of icing protective equipment using same key as below.
4 - Average cost per year for icing damage repairs: 0 = 0 dollars, 1 = 0-$250, 2 = 250-$500, 3 = 500-$1000, 4 = 1000-$5000, 5 = 5000-$10,000, 6 =>$10,000.
5 - S = sometimes, O = often.

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation[1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Connecticut (cont.) | | | | | | | |
| 6. WLHV-FM: Hartford (Meriden) D. Dornfeld | B = 213<br>27<br>T = 241 | M-S | 0 | 1 | Diminished signal | S | M |
| | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | Total broadcast outage | S | S |
| | | | | | Wide-band FM antenna currently in use but not adequate - may install antenna heaters in near future. | | |
| 7. WESU-FM: Middletown R. Stoller | 107<br>8<br>114 | I | 0 | 0 | No problems in 4 yr. history of present set-up (small tower) | | |
| | | | | | Icing not a problem - no protective devices in use | | |
| 8. WSLX-FM: New Canaan M. Cashian | 145<br>12<br>165 | I | 0 | 1 | Icing not a problem - no protective devices in use | | |
| | | | | | No problems since installed 8/84 (small tower) | | |
| 9. WTNH-TV: New Haven B. Russo | 195<br>277<br>472 | M | 2 | 3 | Diminished signal | S | M |
| | | | | | Falling ice damage to equipment | O | M |
| | | | | | Falling ice damage to surrounding property | O | M |
| | | | | | Total broadcast outage | S | M |
| | | | | | Ice detector-activated TV antenna heaters | S | M |
| 10. WLYQ-FM: Norwalk C. Mills | 35<br>114<br>149 | I | 2 | 1 | Diminished signal | S | L |
| | | | | | Protective devices prevent most problems (manually activated FM antenna heaters left on all winter) | | |
| 11. WEDN-TV: Norwich J. Kean | 160<br>146<br>306 | L | 1 | 1 | Diminished signal | S | L |
| | | | | | Protective devices prevent most problems (temp and sleet activated TV antenna heaters) | | |
| 12. WNPR-FM: Norwich J. Kean | 160<br>146<br>306 | L | 0 | 1 | Diminished signal | S | M |
| | | | | | Falling ice damage to equipment | S | I |
| 13. WBCT-TV: Seymour J. Goertz | 189<br>90<br>279 | L | 1 | 1 | Wind damage to equipment | S | I |
| | | | | | Falling ice damage to equipment | S | L |
| | | | | | Protective devices prevent most problems (radomes on microwave dishes, steel grating ice shields on transmission lines) | S | L |

| Station:Offices<br>(Mast location, if different)<br>Respondent | Transmitter Elevation[1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Connecticut (cont.) | | | | | | | |
| 14. WSTC-AM/WYRS-FM:<br>C. Mills | B = 49<br>114<br>T = 163 | I | 1 | 1 | Protective devices prevent most problems (temp. activated FM antenna heaters) | | |
| 15. WILI-AM: Willimantic<br>C. Rice | 46<br>124<br>170 | L | 0 | 1 | Diminished signal<br>Icing not a problem - no protective devices in use | S | L |
| Massachusetts | | | | | | | |
| 16. WFCR-FM: Amherst<br>(Mt. Lincoln, Pelham)<br>C. Ferguson | 377<br>34<br>411 | M | 1 | 1 | Diminished signal<br>Stretched guys<br>Total broadcast outage<br>Protective devices prevent most problems (manually activated FM antenna heaters) | S<br>S<br>S | M<br>L<br>S |
| 17. WERS-FM: Boston<br>R. Levy | 238<br>8<br>246 | L | 1 | 2 | Protective devices prevent most problems (manually activated FM antenna heaters)<br>Plan to convert to radomes soon | | |
| 18. WRBB-FM: Boston<br>C. Tarver | 48<br>60<br>107 | L | 0 | 1 | Diminished signal<br>Icing not a problem now - no protective devices in use. No problems since at new location in 1983. | S | L |
| 19. WBPC-FM: Charlton | 117<br>24<br>142 | I | 0 | 1 | Stretched or frayed guys<br>Broken guys<br>Icing not a problem - no protective devices in use | S<br>S | M<br>L |
| 20. WIQH-FM: Concord<br>N. Roos | 61<br>9<br>70 | I | 0 | 1 | Diminished signal<br>Total broadcast outage<br>Small tower - have no real icing problems | S<br>2/yr. | S |
| 21. WGAJ-FM: Deerfield<br>J. Hemingway | 263<br>24<br>287 | -- | -- | -- | New installation - no history. | | |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation[1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Massachusetts (cont.) | | | | | | | |
| 22. WAQY-FM: E. Longmeadow<br>K. Jones | B = 267<br>158<br>T = 426 | M | 3 | 0 | Antenna space leased from WWLP-TV, Springfield, MA | | |
| 23. WIXY-AM: E. Longmeadow<br>K. Jones | 110 (4)<br>57<br>167 | L | 0 | 2 | Four-tower directional array<br>Diminished signal<br>Falling ice damage to surrounding property<br>Short, sturdy tower - have no real icing problems<br>No serious problems in 5 yr. history<br>No protective devices in use | <br>S<br>S | <br>L<br>L |
| 24. WALE-AM: Fall River<br>G. Faltus | 4<br>56<br>60 | L | 0 | 1 | Diminished signal<br>Stretched or frayed guys (wind)<br>Wind damage to equipment<br>Ice/snow buildup on satellite dish<br>Icing not a big problem - no protective devices in use | S<br>S<br>S<br>1-2/mo. | L<br>M<br>M |
| 25. WGAW-AM: Gardiner<br>G. Wiley | 335<br>47<br>383 | I | 0 | 1 | Diminished signal<br>Icing not a problem - no protective devices in use | ~3/yr. | |
| 26. WPOE-AM: Greenfield<br>(J. Hemingway) | 76<br>61<br>137 | I | 0 | 1 | Icing not a problem - no protective devices in use. | | |
| 27. WCCM-AM/WCGY-FM:<br>Lawrence (Andover)<br>J. Soucise | 61<br>123<br>184 | -- | 0 | -- | Unknown (new engineer)<br>No protective devices in use | | |
| 28. WJUL-FM: Lowell<br>R. Weston | -<br>9<br>- | I | 1 | 1 | Total broadcast outage<br>Protective devices prevent most problems (temp-activated FM antenna heaters) | S | L |
| 29. WMLN-FM: Milton<br>A. Frank | 67<br>29<br>96 | L | 2 | 1 | Experienced much signal reflection prior to installation of temp. activated FM antenna heater in early 1983 - no problem since. | | |

| Station:Offices<br>(Mast location, if different)<br>Respondent | Transmitter Elevation [1] | Icing Degree [2] | Maintenance [3] | Repairs [4] | Specific Problems, Frequency [5] and Degree [2] | | |
|---|---|---|---|---|---|---|---|
| Massachusetts (cont.) | | | | | | | |
| 30. WNEV-TV: Boston<br>(Newton)<br>A. Rouff | B = 37<br>324<br>T = 361 | S | 5 | 6 | Diminished signal<br>Wind damage to equipment<br>Falling ice damage to equipment<br>Falling ice damage to surrounding peoperty<br>Ice detector activated TV antenna heaters, dish radomes, emergency stand-by antenna in place | S<br>S<br>S<br>S | S<br>S<br>M<br>S |
| 31. WZOU-FM : Boston<br>(Newton)<br>P. Hurd | 30<br>411<br>441 | S | 4 | 4 | Wind damage to equipment<br>Falling ice damage to equipment<br>Falling ice damage to surrounding property<br>Antenna radomes, iron grillwork ice shields | S<br>S<br>S | L<br>M<br>S |
| 32. WJCC-AM: Norfolk<br>S. Callahan | 68<br>69<br>137 | L | 0 | 1 | Diminished signal<br>Stretched or frayed guys<br>Total broadcast outage<br>Icing not a big problem - no protective devices in use | S<br>S<br>S | L<br>L<br>L |
| 33. WMNB-FM: N. Adams<br>P. Willey | 616<br>46<br>661 | L | 2 | 1 | Diminished signal<br>Protective devices prevent most problems (manually activated FM antenna heaters left on all winter) | S | M |
| 34. WHMP- FM<br>Northampton<br>R. Rzeszutek | 193<br>70<br>263 | I | 1 | 1 | Diminished signal<br>Protective devices prevent most problems (fiber-glass radomes over FM antenna) | S | L |
| 35. WUNH-AM: Pittsfield<br>R. Backstrom | 309<br>67<br>376 | I | 0 | 1 | Falling ice damage to surrounding property<br>Total broadcast outage (wind)<br>Icing not a big problem - no protective devices in use | S<br>S | M<br>S |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation [1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems | Frequency[5] | Degree[2] |
|---|---|---|---|---|---|---|---|
| Massachusetts (cont.) | | | | | | | |
| 36. WUPE-FM: Pittsfield<br>R. Backstrom | B = 540<br>46<br>T = 586 | L | 1 | 1 | Wind damage to equipment | S | M |
| | | | | | Falling ice damage to equipment | S | M |
| | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | Total broadcast outage | S | S |
| | | | | | Protective devices prevent most problems (precip/ temp-activated FM antenna heaters) | | |
| 37. WSTG-TV: Rehoboth<br>J. Rogers | 38<br>293<br>331 | M | 3 | -- | Has been on the air only two winters | | |
| | | | | | Wind damage to equipment | S | L |
| | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | Temp-activated heaters for radomes on TV and FM antennae | | |
| 38. WESO-AM: Southbridge (Dudley)<br>R. LaVallee | 195<br>70<br>265 | I | 0 | 0 | Tower is overdesigned for its present capacity, no problems experienced in 30 yr. history | | |
| 39. WQVR-FM: Southbridge (Dudley)<br>R. LaVallee | 250<br>46<br>296 | I | 2 | 0 | Protective devices prevent most problems (manually-activated FM antenna heaters left on all winter) | | |
| 40. WGGB-TV: Springfield (Holyoke)<br>T. Gratowski | 366<br>47<br>413 | L | 1 | 3 | Diminished signal | S | L |
| | | | | | Falling ice damage to surrounding property | S | L |
| | | | | | Total broadcast outage | S | L |
| | | | | | Protective devices prevent most problems (manually-activated TV antenna heaters) | | |
| 41. WMAS-AM/FM: Springfield<br>B. Shotwell | 22<br>107<br>129 | L | 0 | 1 | Diminished signal | S | L |
| | | | | | Icing not a problem - no protective devices in use | | |
| 42. WWLP-TV: Springfield<br>L. Chenenvert | 267<br>158<br>426 | L | 3 | 1 | Protective devices prevent most problems (ice detector-activated TV antenna heaters) | | |

| Station: Offices (Mast location, if different) Respondent | Transmitter Elevation [1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| <u>Massachusetts</u> (cont.) | | | | | | | |
| 43. WYAJ-FM: Sudbury | B = 67 | L | 0 | 1 | Diminished signal | S | I |
| G. Beth | 21 | | | | Wind damage to equipment | S | [illegible] |
| | T = 88 | | | | Total broadcast outage | S | I |
| | | | | | Icing not a big problem - no protective devices in use (small tower) | | |
| 44. WPEP-AM: Taunton | 64 | I | 0 | 1 | Stretched or frayed guys | | |
| S. Callahan | 56 | | | | Icing not a problem - no protective devices in use | | |
| | 120 | | | | | | |
| 45. WCRB-FM: Waltham (Needham) | 38 | L | 1 | 1 | Wind damage to equipment | 1/6yr | |
| D. Maxson | 366 | | | | Falling ice damage to equipment | 1/6yr | |
| | 404 | | | | Protective devices prevent most problems (radomes on FM antenna) | | |
| 46. WSRS-FM: Worcester | 335 | L | 1 | 1 | Protective devices prevent most problems (FM antenna heaters) | | |
| D. Gaffney | 59 | | | | | | |
| | 394 | | | | | | |
| 47. WTAG-AM: Worcester | 250 (1) 250 (2) | L | 0 | 1 | Three-tower directional array | | |
| J. Andrews | 99 116 | | | | Diminished signal | S | I |
| | 349 366 | | | | Falling ice damage to equipment | S | I |
| | | | | | Total broadcast outage | S | L |
| | | | | | Tower collapse (wind - 1938 (3), 1954 (1) | | |
| <u>Maine</u> | | | | | | | |
| 48. WLAM-AM: Auburn | 61 (2) | I | 0 | 0 | Two-tower directional array | | |
| H. Wiles | 56 | | | | Icing not a problem - no protective devices in use | | |
| | 117 | | | | | | |
| 49. WHSN-FM: Bangor | 58 | M | 0 | 1 | Diminished signal | O | S |
| P. Roy | 22 | | | | Total broadcast outage | O | S |
| | 80 | | | | | | |

| Station: Offices (Mast location, if different) Respondent | Transmitter Elevation [1] | | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|---|
| Maine (cont.) | | | | | | | | |
| 50. WPBC-FM: Bangor<br>N. Wetmore | | B = 232<br>44<br>T = 276 | M | 1 | 1 | Diminished signal | S | M |
| | | | | | | Total broadcast outage | S | S |
| | | | | | | Ice shield on the antenna tuning controls | | |
| 51. WZON-AM: Bangor<br>N. Wetmore | 55<br>123<br>178 | 55<br>62<br>117 | I | 0 | 2 | Stretched or frayed guys | S | L |
| | | | | | | Wind damage to equipment | S | M |
| | | | | | | Falling ice damage to equipment | S | L |
| | | | | | | Falling ice damage to equipment | S | L |
| | | | | | | Falling ice damage to surrounding property | S | L |
| | | | | | | Total broadcast outage | S | L |
| | | | | | | Icing not a big problem - no protective devices in use | | |
| 52. WIGY-FM: Bath<br>R. Brace | | 43<br>110<br>152 | L | 1 | 1 | Diminished signal | S | L |
| | | | | | | Protective devices prevent most problems (teflon-coated FM antenna elements) | | |
| 53. WQDY-FM: Calais<br>R. Holst | | 61<br>85<br>146 | M | 2 | 2 | Diminished signal | S | S |
| | | | | | | Falling ice damage to equipment | S | L |
| | | | | | | Total broadcast outage | S | M |
| | | | | | | Manually activated antenna heaters | | |
| | | | | | | Plan to install a VSWR monitor/activator for heaters | | |
| 54. WKSQ-FM: Ellsworth<br>M. Osborne | | 88<br>89<br>178 | L | 2 | 1 | Diminished signal | S | L |
| | | | | | | Temp - activated antenna heaters | | |
| 55. WHOU-AM/FM: Houlton<br>N. Wetmore | | 114<br>128<br>242 | L | 1 | 1 | Wind damage to equipment | S | [illegible] |
| | | | | | | Protective devices prevent most problems (manually activated FM antenna heaters) | | |
| 56. WCBB-TV: Lewiston (Litchfield)<br>R. Desjardins | 210<br>193<br>403 | 210<br>77<br>287 | M | 1 | 3 | Falling ice damage to equipment | S | L |
| | | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | | Downed powerlines | S | M |
| | | | | | | Manually-activated antenna heaters, radomes on microwave dishes | | |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation [1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Maine (cont.) | | | | | | | |
| 57. WKZS-FM: Lewiston | B = 143 | L | 1 | 1 | Diminished signal | S | L |
| H. Wiles | 152 | | | | Protective devices prevent most problems (manually-activated antenna heaters) | | |
| | T = 296 | | | | | | |
| 58. WMTW-TV: Poland Springs | 1906 | S | 3 | 1 | Diminished signal | S | L |
| (Mt. Washington, NH) | 37 | | | | Stretched or frayed guys | S | M |
| J. Ricker | 1943 | | | | Wind damage to equipment | S | M |
| | | | | | Falling ice damage to equipment | O | M |
| | | | | | Glaze ice/high wind damage to microwave dish | ~2-3/y | |
| | | | | | Icing occurs 8-9 months of year | | |
| | | | | | Protective devices and short tower prevent most problems (metal tower radome, fiberglass TV antenna radome) | | |
| 59. WCSH-TV: Portland | 375 | S | 5 | 6 | Diminished signal | S | L |
| R. Dean | 398 | | | | Wind damage to equipment | S | L |
| | 773 | | | | Falling ice damage to equipment | O | S |
| | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | Total broadcast outage | S | L |
| | | | | | Tower collapse (icing-3/83) | | |
| | | | | | Temp-activated antenna heaters, radomes on antenna and microwave dish, ice shield (steel I-beams w/oak boards & chain link fence on roof of transmitter building) | | |
| 60. WDCS-FM: Portland | 23 | I | 0 | 1 | Protective devices prevent most problems (radomes on FM antenna) | | |
| G. Terwilliger | 88 | | | | | | |
| | 111 | | | | | | |
| 61. WJBQ-FM: Portland | 76 | L | 0 | 1 | Diminished signal | S | L |
| (Gorham) | 142 | | | | Wind damage to equipment | S | L |
| G. Terwilliger | 218 | | | | Total broadcast outage | S | L |
| | | | | | Icing not a big problem - no protective devices in use | | |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation[1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Maine (cont.) | | | | | | | |
| 62. WMER-AM: Portland<br>(Westbrook)<br>G. Terwilliger | B = 15<br>54<br>T = 69 | I | 0 | 1 | Three-tower directional array<br>Icing not a problem - no protective devices in use | | |
| 63. WYNZ-AM: Portland<br>(Scarborough)<br>J. Goran | 15<br>74<br>89 | L | 0 | 0 | Icing not a big problem - no protective devices in use.<br>(based only on last two winters) | | |
| 64. WYNZ-FM: Portland<br>J. Goran | 23<br>69<br>91 | M | 2 | 1 | Diminished signal<br>Falling ice damage to equipment<br>Falling ice damage to surrounding property<br>No damage in last two years<br>Protective devices prevent most problems (manually activated FM antenna heaters) | S<br>S<br>S | L<br>L<br>L |
| 65. WRKD-AM/WMCM-FM:<br>(Rockland)<br>E. Hammond | 0<br>79<br>79 | L | 2 | 1 | Diminished FM signal<br>Protective devices prevent most problems (temp-activated FM antenna heaters) | S | L |
| New Hampshire | | | | | | | |
| 66. WJYY-FM: Concord<br>L. Collins | 283<br>24<br>308 | L | 0 | 0 | Diminished signal<br>Protective devices prevent most problems (radomes on FM antenna) | S | L |
| 67. WKXL-AM: Concord<br>L. Leblanc | 87<br>94<br>181 | I | 1 | 0 | Icing not a problem - no protective devices in use.<br>Never lost airtime due to icing. | | |
| 68. WKXL-FM: Concord<br>L. Leblanc | 194<br>30<br>224 | I | 1 | 0 | Protective devices prevent most problems (manually-activated FM antenna heaters)<br>Never lost airtime due to icing, since 1946. | | |
| 69. WBNC-AM: Conway<br>S. Sherman | 137<br>73<br>210 | I | 0 | 1 | Diminished signal<br>Icing not a problem - no protective devices in use | S | L |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation [1] | | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|---|
| New Hampshire (cont.) | | | | | | | | |
| 70. WMWV-FM: Conway<br>S. Sherman | B = 372<br>24<br>T = 396 | | L | 0 | 1 | Diminished signal<br>Icing not a problem - no protective devices in use | S | L |
| 71. WDER-AM: Derry<br>K. Slotin | 140<br>90<br>230 | (4) | I | 0 | 1 | Four-tower directional array<br>Icing not a problem - no protective devices in use | | |
| 72. WNDS-TV: Derry<br>(Hudson)<br>G. Chadwick | 122<br>152<br>274 | | L | 1 | 1 | Diminished signal<br>Stretched or frayed guys<br>Wind damage to equipment<br>Total broadcast outage<br>Protective devices prevent most problems (manually - activated TV antenna heaters)<br>"Most problems are wind related" | S<br>S<br>S<br>S | M<br>L<br>S<br>L |
| 73. WTSN-AM: Dover<br>P. LeBlanc | 18<br>62<br>81 | (4) | M | 0 | 1 | Four-tower directional array<br>Icing not a problem - no protective devices in use. | | |
| 74. WDCR-AM/WFRD-FM: Hanover (W. Lebanon)<br>G. Bourozikas | 324<br>49<br>404 | | I | 1 | 1 | Diminished signal<br>Protective devices prevent most problems (manually - activated FM antenna heaters) | S | L |
| 75. WKBK-AM: Keene<br>L. Collins | 146<br>53<br>200 | | I | 0 | 1 | Icing not a problem - no protective devices in use | | |
| 76. WTSL-AM: Lebanon<br>D. Clarke | 160<br>46<br>206 | | I | 0 | 1 | Icing not a problem - no protective devices in use | | |
| 77. WFEA-AM: Manchester<br>S. Vanni | (1) 61<br>114<br>175 | (2) 61<br>61<br>122 | I | 0 | 0 | Three-tower directional array<br>Icing not a problem - no protective devices in use | | |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation [1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| New Hampshire (cont.) | | | | | | | |
| 78. WGIR-FM: Manchester<br>W. Small | B = 390<br>38<br>T = 428 | MS | 2 | 1 | Diminished signal<br>Falling ice damage to equipment<br>Manually activated FM antenna heaters left on all winter.<br>Had only one damage incident in last 6½ years | S<br>S | M<br>M |
| 79. WGIR-AM: Manchester<br>W. Small | 61 (4)<br>91<br>152 | L | 0 | 1 | Four-tower directional array<br>Diminished signal<br>Icing not a big problem - no protective devices in use | <br>S | <br>L |
| 80. WMDK-FM: Peterborough<br>D. Buren | 594<br>37<br>632 | M | 1 | 1 | Diminished signal<br>Broken guys<br>Wind damage to equipment<br>Falling ice damage to equipment<br>Falling ice damage to surrounding property<br>Manually-activated FM antenna heaters left on all winter | S<br>S<br>S<br>S<br>S | L<br>M<br>L<br>M<br>S |
| 81. WASR-AM: Wolfboro<br>A. Severy | 171<br>63<br>234 | L | 0 | 0 | Icing not a problem - no protective devices in use | | |
| Rhode Island | | | | | | | |
| 82. WCVY-FM: Coventry<br>S. Jurczyk | 94<br>12<br>107 | I | 0 | 1 | Diminished signal<br>Total broadcast outage<br>Icing not a problem - no protective devices in use | S<br>S | L<br>L |
| 83. WRIU-FM: Kingston<br>D. Egan | 50<br>123<br>173 | L | 1 | 1 | Protective devices prevent most problems (temp-activated FM antenna heaters)<br>Will install ice detector - summer '85 | | |
| 84. WOTB-FM: Middletown<br>D. Egan | 67<br>21<br>89 | I | 0 | 1 | Diminished signal<br>Wind damage to equipment<br>Falling ice damage to surrounding property<br>Icing not a problem - no protective devices in use | S<br>S<br>S | L<br>L<br>L |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation[1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Rhode Island (cont.) | | | | | | | |
| 85. WADK-AM: Newport<br>R. Sullivan | B = 9<br>98<br>T = 107 | I | 0 | 1 | Broken guys<br>Icing not a problem - no protective devices in use | S | L |
| 86. WEAN-AM/WPJB-FM:<br>Providence<br>D. Puopolo | 73<br>149<br>223 | | | | Diminished signal<br>Wind damage to equipment<br>Falling ice damage to equipment<br>Total broadcast outage<br>Protective devices prevent most problems (ice detector/temp-activated FM antenna heaters)<br>Icing events fluctuate from 0 to 3-4 times/yr. | S<br>S<br>S<br>S | M<br>L<br>M<br>M |
| 87. WHJJ-AM: Providence<br>(Riverside)<br>P. Philbrook | 3<br>134<br>137 | L | 1 | 1 | Two-tower directional array<br>"Extra heavy-duty tower construction and few freezing rainstorms responsible for few problems" | | |
| 88. WHJY-FM/WBRU-FM/WHIM-AM:<br>Providence<br>P. Philbrook | 12<br>166<br>181 | L | 1 | 1 | Diminished signal<br>Tower collapse (wind-1954)<br>Freezing rain 2-3 times/yr. | S | L |
| 89. WJAR-TV: Providence<br>(Rehoboth, MA)<br>R. Kane | 69 69<br>305 152<br>373 221 | I | 1 | 1 | Diminished signal<br>Falling ice damage to surrounding property<br>Protective devices prevent most problems (temp/moisture-activated FM and TV antennae heaters) | S<br>S | L<br>I |
| 90. WKRI-AM: W. Warwick<br>J. Mattias | 76<br>61<br>137 | I | 0 | 1 | Total broadcast outage<br>Tower collapse (wind, rusted guys)<br>Icing not a problem - no protective devices in use | S<br>Once | L |
| Vermont | | | | | | | |
| 91. WKVT-AM: Brattleboro | 101<br>46<br>147 | L | 0 | 1 | Icing not a problem - no protective devices in use | | |
| 92. WKVT-FM: Brattleboro | 469<br>46 | M | 0 | 0 | Diminished signal<br>Protective devices prevent most problems (wide- | ~2/yr | |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation[1] | | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|---|
| Vermont (cont.) | | | | | | | | |
| 93. WCAX-TV: Burlington (Mt. Mansfield) T. Teffner | B = 1219<br>40<br>T = 1259 | | S | 3 | 0 | Diminished signal | S | L |
| | | | | | | Falling ice damage to equipment | S | L |
| | | | | | | Protective devices prevent most problems (manually-activated TV antenna heaters, wooden transmission line ice shields) | | |
| 94. WETK-TV: Burlington (Mt. Mansfield) R. Whitcomb | 1259<br>32<br>1291 | | M | 3 | 1 | Diminished signal | S | M |
| | | | | | | Wind damage to equipment | S | M |
| | | | | | | Falling ice damage to equipment | S | M |
| | | | | | | Falling ice damage to surrounding property | S | M |
| | | | | | | Protective devices prevent most problems (ice detector-activated TV antenna heaters) | | |
| 95. WJOY-AM/WQCR-FM: Burlington D. Snyder | 87<br>110<br>197 | | I | 1 | 1 | Diminished signal | S | I |
| | | | | | | Falling ice damage to equipment | S | I |
| | | | | | | "Freezing rain occurs about 6 times/yr but severity of events is moderated by Lake Champlain proximity." | | |
| | | | | | | Protective devices prevent most problems (temp-activated FM antenna heaters) | | |
| 96. WVMT-AM: Burlington (Colchester) M. Seguin | 31<br>90<br>122 | (3) | I | 0 | 1 | Three-tower directional array | | |
| | | | | | | Diminished signal | S | L |
| | | | | | | Icing not a big problem - no protective devices in use | | |
| 97. WVNY-TV: Burlington (Mt. Mansfield) R. McClintock | 1280<br>92<br>1372 | | M | 3 | 3 | Diminished signal | S | M |
| | | | | | | Wind damage to equipment | O | S |
| | | | | | | Falling ice damage to equipment | S | L |
| | | | | | | Falling ice damage to surrounding property | S | L |
| | | | | | | Ice detector - activated TV antenna heaters | | |
| | | | | | | Ice shields on FM and two-way antennae | | |
| | | | | | | ½" boiler plate steel shielding over transmission line bridge | | |
| | | | | | | Steel I-beam rafters w/½" boiler plate steel roof on transmitter building | | |

| Station:Offices (Mast location, if different) Respondent | Transmitter Elevation[1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Vermont (cont.) | | | | | | | |
| 98. WXXX-FM: Burlington | B = 131 | - | 0 | - | Installed 11/84 | | |
| H. Ginsberg | 37 | | | | Diminished signal (4 times last winter) | S | M |
| | T = 168 | | | | No protective devices in use | | |
| 99. WIUV-FM: Castleton | 151 | L | 0 | 1 | Diminished signal | S | L |
| W. Freeman | 6 | | | | Icing not a big problem - no protective devices | | |
| | 157 | | | | in use (short tower) | | |
| 100. WWLR-FM: Lyndonville | 296 | L | 2 | 1 | Diminished signal | S | L |
| C. Parker | 26 | | | | Protective devices prevent most problems (temp- | | |
| | 321 | | | | activated FM antenna heaters) | | |
| 101. WSKI-AM: Montpelier | 198 | L | 0 | 1 | Diminished signal | S | L |
| G. Marcotte | 53 | | | | Wind damage to equipment | S | L |
| | 251 | | | | Total broadcast outage | S | L |
| | | | | | Icing not a problem - no protective devices in use | | |
| | | | | | "Can't recall any problems from ice in past 3 yrs." | | |
| 102. WRUT-FM: Rutland | 1291 | S | 2 | 1 | Diminished signal | S | L |
| (Mt. Killington) | 18 | | | | Falling ice damage to equipment | S | M |
| D. French | 1309 | | | | Falling ice damage to surrounding property | S | M |
| | | | | | Total broadcast outage | S | M |
| | | | | | Tower collapse (icing) | once | |
| | | | | | Protective devices prevent most problems (fiberglass | | |
| | | | | | radome on STL dish with temp-activated heaters, | | |
| | | | | | manually-activated FM antenna heaters) | | |
| 103. WSTJ-AM: St. Johnsbury | 226 | I | 0 | 1 | Diminished signal | S | L |
| P. Morton | 56 | | | | Broken guys | S | L |
| | 282 | | | | Falling ice damage to equipment | S | L |
| | | | | | Icing not a problem - no protective devices in use | | |

| Station:Offices<br>(Mast location, if different)<br>Respondent | Transmitter<br>Elevation [1] | Icing Degree[2] | Maintenance[3] | Repairs[4] | Specific Problems, Frequency[5] and Degree[2] | | |
|---|---|---|---|---|---|---|---|
| Vermont (cont.) | | | | | | | |
| 104. WVTB-TV: St. Johnsbury<br>(Burke Mtn.)<br>R. Whitcomb | B = 1032<br>40<br>T = 1072 | M | 3 | 1 | Diminished signal<br>Wind damage to equipment<br>Falling ice damage to equipment<br>Falling ice damage to surrounding property<br>Protective devices prevent most problems (ice detector-activated TV antenna heaters) | S<br>S<br>S<br>S | |
| 105. WCFR-AM/FM: Springfield<br>I. Wilner | 244<br>91<br>335 | I | 1 | 1 | Diminished signal<br>Protective devices prevent most problems (manually-activated FM antenna heaters) | S | L |
| 106. WNHV-AM: White River Jct.<br>A. Leckart | 134<br>75<br>209 | I | 0 | 1 | Icing not a problem - no protective devices in use | | |
| 107. WNHV-FM: White River Jct.<br>(W. Lebanon, NH)<br>A. Leckart | 305<br>61<br>366 | I | 1 | 1 | Protective devices prevent most problems (manually-activated FM antenna heaters) | | |
| 108. WNNE-TV: White River Jct.<br>(Mt. Ascutney)<br>J. Alvin | 920<br>49<br>969 | S | 4 | 4 | Diminished signal<br>Wind damage to equipment<br>Falling ice damage to equipment<br>Total broadcast outage<br>Temp-activated heaters on TV antenna and dishes | S<br>O<br>O<br>S | M<br>S<br>S<br>M |