

Abridgment

Solutions To Improve Ice and Snow Control Management on Road, Bridge, and Runway Surfaces

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An overview of the products and services offered by a full-service commercial weather support company is provided. Solutions are presented to make winter travel safer and to help reduce the billions of dollars spent annually on ice and snow control in North America. The solutions offered come from unique meteorological (pavement- and atmospheric-sensing) instrumentation, data processing units, tailored microcomputer software, a numerical forecasting model that projects pavement and weather conditions, and a specialized weather-forecasting center established to support the transportation industry. Methods to improve the interface between the provider of specialized weather equipment and unique pavement forecasts and the customer who relies on real-time pavement weather information and forecasts to reduce ice and snow control budgets are described.

Significant progress has been achieved in meteorology since Aristotle wrote *Meteorologica* in 340 B.C. and the study of weather became recognized as a science rather than a phenomenon based on superstition, imagination, and acts caused by Greek gods. *Meteorologica* was the "weather bible" for scientific research for almost 2,000 years. Little progress was made until the 16th and 17th centuries, when weather-measuring instruments were introduced, allowing scientists to document and study weather. The greatest growth of meteorology resulted from the birth of the aviation industry after the flight at Kitty Hawk in 1903. Figure 1 gives several historical weather support events.

To support the aviation industry, the U.S. Weather Bureau (now the U.S. National Weather Service) established weather-observing and forecasting facilities at air terminals across the nation. Weather forecasts and predictions can only be as accurate as the information on which they are based. Nearly all weather forecasts are based in part, if not completely, on the surface aviation report, which is taken, recorded, and disseminated from airports around the world. Airport weather observations are generally used by the media as the official weather report, and the official weather forecast for the city, state, and region is based on the surface aviation report. The report is generally available only once per hour. It is accurate and may be timely enough for aviation, but it does not contain surface (pavement) weather information. Not until the mid-1970s were airports in North America introduced to a weather-sensing technology with instrumentation that provided runway-

specific temperature, moisture, and information on deicing chemical concentration. In 1982 St. Louis, Missouri, was the first city to purchase and use a street-monitoring system for ice and snow control management. Currently, Road/Runway Weather Information Systems (RRWISs) are operational in 42 states and 6 Canadian provinces. They are installed in more than 90 North American airports and indicate the following (also see Figure 2):

- Surface (pavement) temperatures are obtained from solid-state electronic devices installed in the roadway or runway. The sensors are usually constructed of materials with thermal characteristics similar to those of common pavement materials. Their performance is not degraded by climatic conditions, traffic, or ice-control chemicals. The tested and proven surface sensors are thermally passive and have a stable operating range from -30°C to $+50^{\circ}\text{C}$.
- Subsurface temperature probes are installed directly below the surface sensor at a depth near 40 cm and provide heat flux information primarily for computer models designed to predict pavement temperature. Frost depth information is also used by highway agencies to regulate truck routing on the basis of the frost level beneath the road surface. The sensor is accurate from -30°C to $+50^{\circ}\text{C}$.
- The onset and termination of any type of hydrometeors (including precipitation) in the air is detected by sensing interruptions in its infrared optical beam.
- Pavement condition statuses are dry, wet (above 0°C), wet (not frozen at or below 0°C), snow or ice (at or below 0°C), dew, frost, and absorption.
- Chemical factor is a relative indicator of the deicing or anti-icing chemical present in the moisture on the surface sensor.
- Air temperature is measured over a range from -62°C to $+70^{\circ}\text{C}$.
- Relative humidity generally ranges from 10 to 100 percent.
- Wind direction and speed sensors have an operating range of 360 degrees and record speeds up to 215 km/hr.

The remote processing unit of the RRWIS gathers data from all connected sensors and processes, stores, and transmits these data (surface temperature, subsurface temperature, air temperature, relative humidity, and precipitation).

<u>EVENT</u>	<u>YEAR</u>
* ARISTOTLE wrote 'METEOROLOGICA'.....	340 B.C.
* Thermometer/Barometer.....	17TH Century
* U.S. Weather Bureau.....	1870
* 'KITTY HAWK' Flight.....	1903
* Surface Sensors For Runways.....	1970s
* Roadway Surface Sensors (City of Saint Louis, MO).....	1982
* Pavement Specific Forecasting Center Established (St. Louis, MO).....	1986

FIGURE 1 Historical weather support events.

•Pavement TEMPERATURE At The Surface Head

PAVEMENT STATUSES

- DRY
- WET (Pavement Temperature Above Freezing)
- WET (Not Frozen At Or Below Freezing)
- SNOW - ICE (At Or Below Freezing)
- DEW

CHEMICAL DETECTION

- CHEMICAL FACTOR (Deicing Chemical Present)

FIGURE 2 Surface sensor information.

PAVEMENT-SPECIFIC WEATHER FORECASTING

Early in 1986 a new type of meteorological forecasting center was established solely for the prediction of pavement temperatures and pavement weather conditions. This specialized center is staffed by meteorologists who base their forecasts not only on data from pavement weather stations and atmospheric observations but also on weather information provided by federal agencies in the United States and Canada.

Pavement Temperature and Pavement Condition Prediction

Pavement-specific temperature and weather forecasts are generated using site-specific roadway or runway data with forecast input data from meteorologists. Data are processed with a numerical model on the basis of the heat balance equation. Pavement prediction models require site-specific surface and subsurface data for initialization and are based on the heat balance of the pavement surface. The heat balance equation is expressed as follows:

$$\begin{aligned}
 0 &= \text{heat in} - \text{heat out} \\
 &= (\text{sun's heat} + \text{air's heat} + \text{clouds' heat} \\
 &\quad + \text{heat of condensation} \\
 &\quad + \text{turbulent heat} + \text{ground heat}) \\
 &\quad - \text{heat loss from pavement}
 \end{aligned}$$

or

$$RN + H + S + LE = 0$$

where

- RN = net radiation,
- H = heat exchange with the air,
- S = heat exchange with the pavement structure, and
- LE = latent heat exchange.

Ice and Snow Control Forecast Service Bulletin

Pavement weather bulletins are issued three times per day (early morning, early afternoon, and evening) to subscribers. The prediction bulletin projects pavement and weather parameters that affect ice and snow control procedures over a 24-hr period. Graphically presented information includes the following (also see Figure 3):

1. A pavement temperature forecast: This display shows the temperature profile forecast for the next 24 hr in 20-min intervals. An indicator for a temperature of 32°F (0°C) is displayed when predicted temperatures are near freezing.
2. A freezing-temperature indicator: When forecast pavement temperatures are equal to or less than 32°F, an indicator appears on the line directly below the temperature forecast graph for all times meeting the freezing criteria.
3. A precipitation and surface condition forecast: The forecast graph shows what type of precipitation is expected, the start and finish times, and the length of time that the surface will remain wet.
4. A snow accumulation forecast: This portion of the graph depicts the snow depth forecast (in inches or centimeters) for the valid period of the forecast.
5. A wind speed and direction forecast: This gives the mean wind speed and wind direction forecast for 3-hr intervals during the valid period of the forecast.
6. A mean air temperature and windchill forecast: This gives the mean air temperature and windchill every 3 hr over the valid period of the forecast.
7. A forecaster's discussion: The forecaster who issues the bulletin provides weather decision impact information in plain language.

PAVEMENT-SPECIFIC FORECASTS IN NORTH AMERICA

The decision to establish a facility specifically to provide ice and snow control weather-forecasting support was greatly

national Winter Cities Corporation (IWCC) in Edmonton, Canada. The IWCC is a nonprofit organization formed to promote the economic advantage of winter.

USING PAVEMENT-SPECIFIC INFORMATION FOR OPERATIONAL DECISIONS

An evaluation of the SCAN 16 EF roadway weather information system installed at four locations in New Jersey stated the following (2):

Utilization of the system leads to reduced deicing chemical usage and a savings in manpower and equipment costs. By monitoring pavement temperatures, Region IV [NJDOT] maintenance personnel were able to delay spreading deicing chemicals by up to three hours. In some cases, these delays resulted in the saving of up to one deicing chemical application per storm. These same delays, combined with delays in crew call-outs and early crew releases, resulted in savings in manpower and equipment costs. The system's greatest potential appears to be a real time statewide roadway weather information system interactively shared with other agencies. Some of the possible benefits: 1) reduced deicing chemical usage (a saving of 54,170 dollars for each spread saved statewide), 2) improved weather forecasts for the state of New Jersey, 3) reduced snow and ice related accidents, 4) other agency interaction (e.g. aeronautics could use the information to assist pilots in developing flight plans, data from the system could be used by the State Police to supplement their Emergency Management System, etc.), 5) savings in manpower and equipment use. A savings (state wide) of 11,500 dollars per hour could be realized for each hour saved by delaying crew call-outs and expediting crew releases. The SCAN System 16 EF works. It is in the best interest of the State of New Jersey and the general public to expand the system to provide statewide coverage.

SUMMARY

Technological advances continue in weather instrumentation, remote pavement sensing, computer design and function, computer software, and communications. Although they are relatively new, roadway and runway weather stations with pavement-specific data provide improved information on which

to base ice and snow control management decisions. Numerical weather prediction models are now more accurate and provide the meteorologist with much more information than was previously available to make forecasts.

Pavement weather events directly affect all pavement maintenance decisions. Therefore, pavement weather data and pavement-specific forecasts should be considered by agencies responsible for ice and snow control. Pavement-specific weather reports and forecasts allow ice and snow control officials to be proactive instead of reactive. This can reduce the billions of dollars spent each year on ice and snow control in North America. Making the correct ice and snow decision involves understanding meteorological processes as they affect pavements. When will precipitation start? Will it be rain, snow, mixed, or will rain freeze as it strikes the surface? How much will there be and how long will it last? How cold will the pavement get? What chemicals are effective? Specialized workshops and seminars can improve the use of pavement weather information and weather impact forecasts for ice and snow control on roadways, bridges, and runways. Weather forecasting will not be an exact science in the foreseeable future, but progress is being made. Surface- (pavement-) specific weather information and advances in data collecting and processing and numerical modeling techniques are improving weather support service to ice and snow control managers.

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