

## SOLUTIONS TO IMPROVE ICE AND SNOW CONTROL MANAGEMENT ON ROAD, BRIDGE, AND RUNWAY SURFACES

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### ABSTRACT

This paper presents solutions to reduce the estimated 3 BILLION dollars spent annually on ice and snow control in North America.

Solutions offered come from unique meteorological (pavement sensing) instrumentation, data processing units that process the pavement data, tailored microcomputer software that displays the pavement data, a microcomputer model that projects pavement conditions, and a specialized weather forecasting center.

The surface sensing system records the pavement temperature, the approximate amount of chemical concentrate on the pavement under wet conditions (chemical factor), whether the pavement is wet or dry and when there is ice, snow or frost on the pavement.

The data processing units collect, analyze, store and format the pavement data for display on computer terminals.

A color graphics software package allows users of the system to view pavement conditions in an enhanced form. Potentially hazardous pavement conditions are color coded for instant recognition.

The temperature forecasting model is based on the heat balance of the pavement surface, using the heat balance equation.

Products and services provided to agencies responsible for maintenance of pavements are generated from a centralized weather forecasting center in St. Louis, Missouri.

### 1. INTRODUCTION

Improving the management of ice and snow control can only be achieved with accurate weather information on which to base sound decisions. Weather information must include pavement specific data. Thousands of dollars can be wasted in a single storm by taking needless actions, or by not initiating remedial treatment at the beginning of the storm. Knowing the current pavement temperature (not to be confused with the air temperature) and the projected pavement temperature is crucial to effective ice and snow control management. Many other weather elements play a significant role in effective snow and ice control, but none more important than the pavement temperature and the pavement conditions. In order to improve management procedures and reduce costs, highway officials and others responsible for maintaining safe pavement surfaces must make decisions on:

- \* If and when to mobilize personnel
- \* What is the correct amount of personnel to do the task
- \* What equipment should be mobilized
- \* What is the correct amount and type of chemical to spread
- \* When to implement each required action

The optimum weather information to base decisions on is:

- \* Accurate information on the predicted storm (when, where, type of precipitation and the intensity)
- \* Accurate pavement temperature information
  - pavement temperature changes and degree of change
  - when will the pavement freeze
  - how long will the pavement remain frozen
- \* Accurate pavement condition information
  - dry
  - wet
  - ice/snow
  - frost
  - chemical concentration on the pavement surface

More than 75 airports and many highways, streets and bridges in North America have surface sensors that monitor pavement temperature and the presence of water, frost, ice and chemicals. Surface (pavement) sensors provide current and trend information to decision makers, but in order to reduce costs, officials must have accurate information on future pavement and weather conditions. Not until the 1986-87 winter season was there a pavement specific forecasting service available in North America. Starting late in 1986 from a centralized facility, meteorologists started to collect the sensor data from pavement observations and then produce a pavement specific forecast for ice and snow control management. This new type of forecast included information on when the precipitation would occur, the type and the amount of precipitation, the wind speed and direction, and when to expect freezing pavement and a graphical pavement temperature projection for a 24 hour period.

## 2. BACKGROUND ON ELECTRONIC PAVEMENT SENSORS

The idea behind pavement sensors has been around for quite a few years. During the 1960s and 1970s, commercial ice detectors attempted to measure the electrical conductivity of water and ice across long metal probes set in pavement. The method had several inherent shortcomings. At best, its accuracy was in the range of 50 to 60 per cent.

During 1973 and 1974, the U. S. Federal Highway Administration (FHWA) sponsored an evaluation of all ice sensor systems then available and field-tested three of them. The question was: could a sensor system be relied upon to activate warning signs automatically as a way to warn motorists when a bridge deck becomes icy?

One system operated on the principals of conductivity. Another detected the latent heat of fusion. The third was a sensor based on the capacitance/conductivity theory. The third sensor operated at all pavement temperatures because it was made of materials with the same thermal characteristics as those of the pavement. The sensor has a flat capacitor beneath its surface to determine if the surface is wet or dry. This, along with a conductivity sampling and a very accurate temperature measurement, enabled the system to determine surface conditions.

After the field test of the three systems, the FHWA concluded that none of them were accurate enough to operate motorist warning signs directly, but that the capacitance/conductivity sensor system could be improved to that point. The sensor was improved, and as of early 1988, the pavement sensor using the flat capacitor was operating successfully at more than 200 highway and airport locations in the United States, Canada and Europe.

### 3. THE SURFACE SENSOR SYSTEM

#### 3.1 The Surface Sensor

The surface sensor is made of a tough epoxy with thermal properties similar to road and runway surfaces. The device contains a capacitor with two elements mounted underneath which measure the dielectric effect of water, ice and snow on the surface. Because the dielectric constant of air differs from that of water, which in turn differs from that of ice and snow, the sensor's output signal reflects conditions on top of the sensor, which closely approximates conditions on the surrounding pavement surface. A flow of electricity across the sensing unit exhibits varying degrees of resistance depending on whether the surface is dry or covered with water, ice or snow.

The sensor is installed flush with the pavement in a 5 1/2 inch/14 centimeter hole, and is color-matched to the pavement surface so that it absorbs and releases light energy at the same rate.

The sensor not only can detect temperature and whether the pavement is dry or wet, but also the amount of chemical concentrate on the pavement under wet conditions. Its design is patented in the United States, Canada, Europe and Japan.

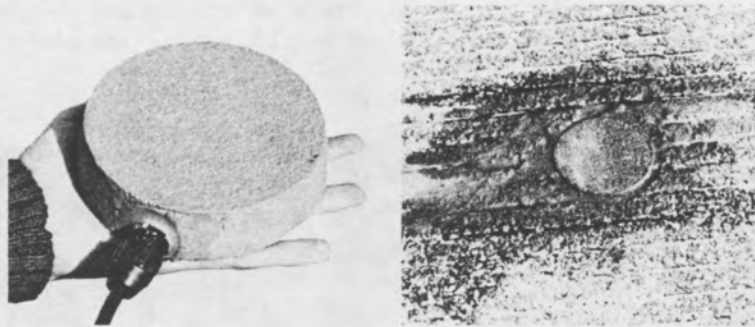


Figure 1. The Surface Sensor (Before and After Installation)

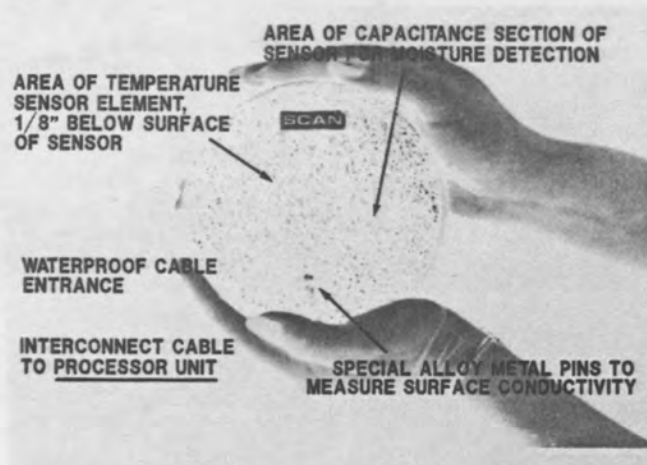


Figure 2. Components of the Surface Sensor

### 3.2 Data Processing Units

All data collected by the sensors are transmitted to Remote Processing Units (RPU), which in turn process the analog signal into a digital format and then relay the information to the Central Processor Unit (CPU). Each RPU receives data from up to four pavement sensors, plus measurements of air temperature and relative humidity detected by atmospheric sensors at the RPU site. Based on the air temperature and the relative humidity, the RPUs calculate the dew-point temperature and transmit this data along with the pavement readings to the CPU.

The CPU analyzes, stores, and arranges the data it receives from the RPUs and displays the information on video display terminals. The video display shows the RPU and sensor locations, the air and surface temperatures, the dew-point temperature, the relative humidity, the wind direction and speed, and the current date and time. The system updates the information on the terminal every 15 seconds.

### 3.3 Formats and Displays

Besides displaying the information in the form of tables, the system can also display custom color graphics tailored to each customer's specifications. All information displayed can be printed in various formats, depending on the information desired.

These formats are called "pages". They include a "status page" showing conditions at each sensor location; a "summary page" providing current data on all surface sensors connected to the system; and a "history page" indicating changing conditions at each sensor location over time.

I.D.O.T. Peoria District Four		Status Page		Time 09:22		March 13, 1984		
McClugage Bridge		RPU #1		Power on at: 16:58 on 03/06/84		Last report: 09:18 on 03/13/84		
Atmospheric Conditions								
Air Temperature		Dew Point Temperature	Relative Humidity	Wind Dir.			Wind Speed MPH	
				Min.	Avg.	Max.	Avg.	Gust.
28		25	89	NW	N	NE	3	8
Surface Conditions								
No.	Sensor Location	Status	Precip	Surface Temperature		Chem. Factor		
1	McClug Br App W/B pl	Wet	Y	33		95		
2	McClug Br App W/B tl	Wet	Y	33		95		
3	McClug Br W/B pl	Chemical Wet	Y	30		95		
4	McClug Br W/B tl	Chemical Wet	Y	30		95		
Enter system command and press [RETURN] : HP 1								

Figure 3. Status Page From One RPU, Four Sensors



I.D.O.T. Peoria District Four							Time 09:23 March 13, 1984			
Sensor # 1							Power on at: 16:58 on 03/06/84			
History Page							McClug Br App W/B pl			
Time	Day	Status	Precip	Rel. Hum.	Chem. Factor	Temperatures			Wind Dir/Vel	
						Surf.	Air	Dew pt.		
09:15	13	Wet	Y	88	95	33	* 28	24	246/ 2	
09:13	13	Wet	Y	90	95	* 33	27	24	248/ 2	
09:00	13	Chemical Wet	Y	90	95	* 31	27	24	240/ 3	
08:53	13	Chemical Wet	Y	92	95	* 30	26	24	242/ 3	
08:40	13	Chemical Wet	* Y	92	95	* 29	26	24	250/ 2	
08:17	13	Chemical Wet	N	92	95	28	* 26	24	241/ 3	
07:57	13	Chemical Wet	N	92	95	* 27	25	23	240/ 3	
06:44	13	Chemical Wet	N	93	95	* 25	24	22	245/ 2	
01:26	13	Chemical Wet	* Y	92	95	24	24	* 22	245/ 3	
22:25	12	Chemical Wet	N	91	95	22	23	20	241/ 3	
22:12	12	Chemical Wet	* N	91	95	* 23	23	20	238/ 5	
22:00	12	Chemical Wet	Y	91	85	25	23	20	230/ 4	
19:19	12	Ice/Snow Alert	Y	93	45	25	23	21	225/ 8	
19:11	12	Ice/Snow Alert	Y	92	45	* 27	23	21	225/ 8	
19:01	12	Ice/Snow Alert	Y	92	45	* 29	24	21	229/10	

Enter system comand and press [RETURN]

Figure 4. History Page Shows Significant Changes From One Surface Sensor

There is also a "graph air page" which shows a graph of changes in air temperature during the previous hour at each RPU; and a "graph surface page" which displays the previous hour's temperature at any surface sensor.

The "significant change page" displays significant changes in temperature, both air and surface, or the dryness or wetness of the pavement at any sensor location.

Color graphics allows the user to view this information in an enhanced form. Using colors selected by the user, the system provides instant recognition of potentially hazardous situations, such as when the pavement status changes from dry to wet or icy. A map option displays information for the entire system.



Figure 5. Sensor Statuses and Atmospheric Data Display for Metropolitan System

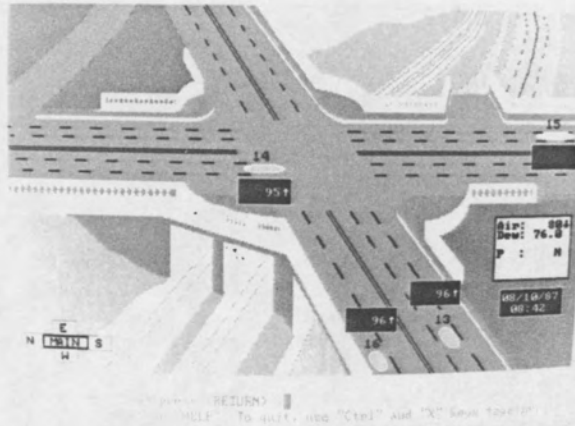


Figure 6. Sensor Status and Atmospheric Conditions Displayed For A Bridge Installation

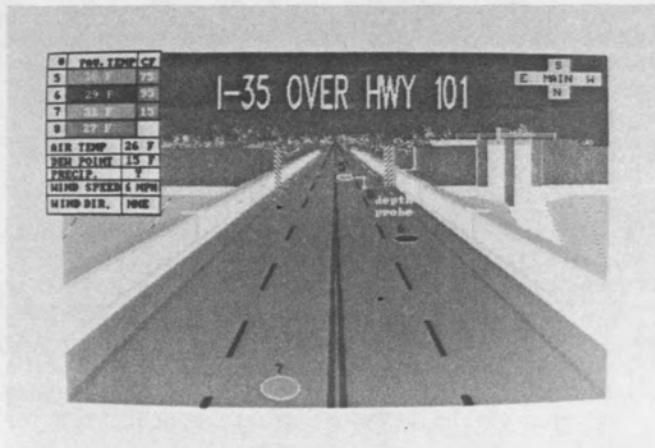


Figure 7. Graphics For Elevated Structure With Surface Sensor and Atmospheric Data Displayed

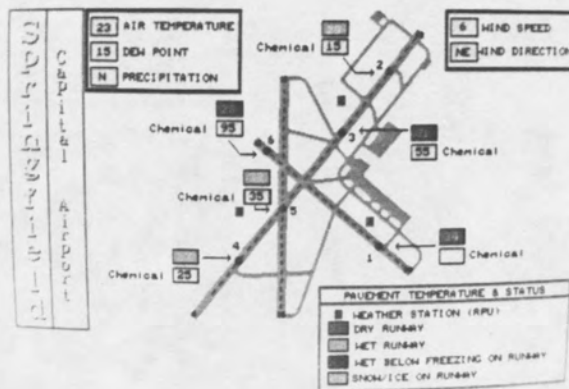


Figure 8. A Runway System Displayed

#### 4. FORECASTING FOR ROAD, BRIDGE AND RUNWAY SURFACES

Being able to forecast what conditions will be in the near future is the main purpose behind this ice detection system. It takes five to 10 times more chemical to remove ice than to prevent it from forming. Therefore, anti-icing (as opposed to de-icing) is much more cost-effective in snow and ice control.

The most important factor in anti-icing is timing, knowing when to apply chemicals. Putting on too much is wasteful, but applying too little too late is also wasteful and allows ice formation to continue.

Knowing the current pavement temperature is important for determining what kind of chemical to use and, to some degree, the application rate. Proper planning of anti-icing requires an accurate forecast of pavement temperature during the next 6 to 24 hours. It is more important to forecast the pavement temperature than air temperature because ice formation is dependent upon the temperature of the pavement surface. The difference between the air and pavement temperature can be as much as 40 degrees Fahrenheit, 22 degrees Celsius.

An accurate forecast of pavement conditions, dry or wet, frozen or unfrozen, is equally vital to the anti-icing effort.

##### 4.1 Pavement Specific Weather Forecast Center

Early in 1986, a new type of meteorological forecasting center was established to concentrate on the prediction of pavement weather conditions. The service provided by this centralized weather forecasting facility offers service to agencies responsible for maintaining pavement surfaces, including roadways, bridges and runways, and for persons responsible for safe and timely traffic operations, which includes motor carrier dispatchers and airport flight control specialist.

The weather center is staffed by professional meteorologists who base their forecasts not only on continuous site specific pavement and atmospheric observations but also on weather information provided by the National Weather Service and the Federal Aviation Administration in the United States and data from the Atmospheric Environmental Service in Canada.

##### 4.2 Pavement Forecasting Center Products and Services

A pavement weather bulletin is issued three times per day (early morning, early afternoon, and evening) to decision makers responsible for ice and snow control. The forecast bulletin provided is graphically presented with projections that have a direct and indirect impact on ice and snow control maintenance procedures.





#### 4.3 Pavement Forecast Enhanced By Numerical Forecasting Model

A numerical computer model was designed and programmed specifically for pavement temperature and pavement weather projections. The model runs on a microcomputer and is based on the heat exchange of a pavement surface, using the heat balance equation:

$RN+H+LE=0$ , where

RN=NET RADIATION

H=HEAT EXCHANGE WITH THE AIR

S=HEAT EXCHANGE WITH THE ROAD STRUCTURE

LE=LATENT HEAT EXCHANGE

Added variables that can be 'fine tuned' for each location are the thermal properties of the road structure, the latitude, and the shadow ratio relating to road or runway topography. The computer model is initialized from pavement sensor information:

- a. The actual pavement temperature at the forecast location.
- b. The actual temperature of the subsurface at depths of about 16 inches/40 centimeters.

Forecast values input into the computer are:

- a. Air temperature
- b. Dewpoint temperature
- c. Cloud amount
- d. Cloud type
- e. Precipitation
- f. Wind speed averages

#### 4.4 Product Accuracy

Verification statistics for twenty-five locations covering the Northern two-thirds of the United States and Southern Canada were compiled for the 1987-88 winter season.

Average Deviation of Forecast Temperature From Actual Temperature  
2.73 degrees Fahrenheit

Average Pavement Freeze Time Error  
1 hour and 31 minutes

Correct Freezing Pavement Forecast  
87%

Precipitation Forecast  
(Start Time) + (Duration) + (Amount of Snow) = 76% Correct

#### 4.5 Acceptance of the Pavement Forecasting Product

During the second season in which the service was offered to customers, over 45 agencies subscribed. Users included 8 State Departments of Transportation, 7 International Airports, 4 Turnpike Authorities, and over 20 Street Departments of large metropolitan cities.

#### 4.6 Product Recognition

The pavement weather forecasting product received the 1988 Award of Excellence in Transportation from the International Winter Cities Corporation (IWCC) in Edmonton, Canada. The IWCC is a non-profit organization formed to promote the economic advantage of winter.

## 5. SUMMARY

Accurate observations of pavement temperatures and conditions (DRY, WET, CHEMICAL WET, and ICE AND SNOW), along with reliable data processing and data storage units that interact with computer terminals, now provide real-time pavement data to meteorologists and maintenance officials. New computer technology has and will continue to improve weather forecasting skills in many areas. A pavement forecasting service is one example of focus and concentration on a specific forecasting problem that has the potential to save large amounts of monies for those responsible for ice and snow control. Consider a large city street department that spends \$5,000 per hour on crew overtime costs. If a correct pavement forecast can save one hour in overtime pay per storm, and the city averages 10 storms per year, the annual saving amounts to \$50,000 just in overtime expenditure.

A meteorological pavement observing network provides valuable meteorological data not available from other sources. With continued expansion of the pavement weather network, increased data could help to improve the accuracy of numerical computer models for many types of weather prediction.

## 6. ACKNOWLEDGMENTS

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