1289

EVALUATION OF BOSCHUNG ICE EARLY WARNING SYSTEM

MICHIGAN DEPARTMENT OF TRANSPORTATION

MATERIALS and TECHNOLOGY DIVISION

EVALUATION OF BOSCHUNG ICE EARLY WARNING SYSTEM

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ABSTRACT

The objective of this project is to determine if the Boschung Ice Early Warning System is capable of detecting the varying surface conditions of a bridge deck and to report them with a reasonable degree of accuracy. Conditions that produce a slippery surface are of the greatest concern. The evaluation was conducted over three winters. The results for all conditions were accuracy rates of 64.7 percent the first winter, 84.2 percent the second winter, and 87.8 percent the third winter. It was concluded that the system is capable of detecting and reporting the condition of a bridge deck with a reasonable degree of accuracy. If it errs, most errors are on the safe side, that is, reporting ice when there is none rather than reporting no ice when there is some.

INTRODUCTION

In July 1984 the Oakland County Road Commission and the Michigan Department of Transportation received an offer from the Boschung Co. to install and maintain their Ice Early Warning System for a period of two winters. The Department selected the bridge carrying westbound I 696 to southbound I 275, and the bridge deck directly under this one which carries northbound I 275 traffic to westbound I 96 for the system. Installation was to be made at the expense of the company, with the Oakland County Road Commission to monitor the system and the Research Laboratory Section to evaluate it. Installation and maintenance of power and telephone lines would be paid by MDOT. The installation was completed in January of 1985.

Since only 34 visual observations were made in the remainder of the 1984-85 winter and, because no visual observations were made in December of 1985, the evaluation was extended one year through the end of January of 1987.

System Installation Description (Appendix, Figure A)

The installation consisted of a separate measuring station for each of the two structures. The output of these measuring stations was connected by cable to a telephone modem located at the MDOT field office on Haggerty Rd in Farmington Hills. From this point the data were transmitted over a leased telephone line to a central computer located in the Oakland County Road Commission building in Pontiac. The data were processed by a personal computer (PC) and displayed on a high resolution color graphics terminal.

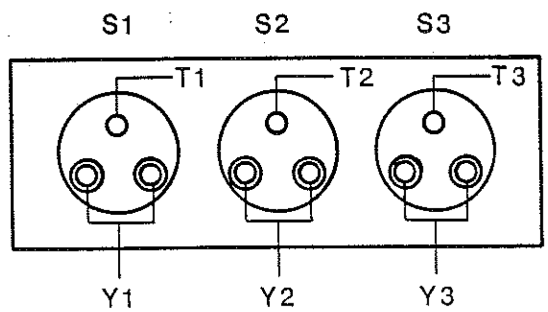
Each measuring station consisted of two atmospheric probes and one surface probe. The atmospheric probes monitored air temperature and checked for the presence of precipitation. The surface probe monitored surface temperature, checked for moisture, and determined the amount of deicing chemicals present. These units, about 4 by 12 in., were placed about mid-span. Although not included at this location, additional sensors are available to measure snow depth, wind direction, and wind speed.

Due to the surface probe operation (described later) measurements of relative humidity was not necessary.

The central computer displayed the current data received from each measuring station. All information received was stored on a hard disk with backup provided by a floppy disk. Historical information stored on the disk could be displayed on the terminal screen. These data were presented in graph form. Although available, a printer was not provided at this location.

A portable terminal having a telephone modem could be used to call the central computer and receive the current data, or a two-hour chronological pattern that led up to the current conditions. One type of terminal produced a hard copy of these data, another type used a video display.

Boschung's surface probe consists of three sensors shown as S1, S2, and S3. Each sensor is capable of measuring a temperature, designated T1, T2, and T3, respectively, for the three sensors. Each is also capable of detecting the presence of moisture and the amount of deicing chemical present in the moisture as indicated in the drawing by Y1, Y2, and Y3.



The ground probes of the Boshung black ice early warning system

Sensor S1 measures T1, which is the actual temperature of the surface, and the electrical conduction Y1, to determine if there is moisture present on the roadway. Sensor S2 measures temperature T2. This sensor is heated or cooled relative to T1. It also measures conductance Y2 to further indicate the presence of moisture. Sensor S3 can only be heated with respect to T1. It also can measure conductance Y3 for a third indication of the presence of moisture.

When sensor S1 indicates a surface temperature, T1, of +4 C or less, sensor S2 begins cooling down to 2 C (adjustable) below T1. Periodically S2 is heated, enabling this sensor to determine if any moisture, Y2, develops in this heating process. If there was not moisture present before the heating, and moisture develops during the heating process, the system's logic assumes the moisture is due to the melting of ice, snow, or frost that had formed on the sensor. Therefore, if the temperature falls another 2 C, ice, snow, or frost will form on the road surface.

The purpose of sensor S3 is to determine if snow or sleet is on the road when that surface is below freezing. This is done by periodically heating S3 to see if any moisture forms which would indicate the presence of ice, snow, or frost on a road surface that is below freezing.

Using the data provided by the air and surface probes a series of alarms are activated and displayed at the central computer. These alarms are described in the Appendix.

Means of Evaluation

To evaluate the system, the Oakland County Road Commission made random visual observations of the condition of each bridge deck. The bridge deck was also checked whenever the system activated alarm 2 or 3. These observations were recorded on a form (Fig. B, Appendix). Each deck was treated as an independent observation even though the observations almost always occurred at the same time. Conditions varied on the two decks due to the sheltering effect the upper deck had on the lower deck. An independent measuring station was installed on each deck to detect these differing conditions.

The visual observations were subsequently compared to the system's stored data for those times that the data from both sources were available. Because of a disk drive malfunction during the 1985-86 winter, all system data between January 10, 1986 and April 10, 1986 were provided by the observer. This was accomplished by the observer calling the dispatcher by radio and asking for the current data being displayed on the system's display terminal. He then copied this information on the bottom of his visual observation form.

The visual observation was compared with the system's data to determine if the two agreed or disagreed. The exact conditions used to determine if the observation agreed or disagreed are described in the Appendix. The air and surface temperatures were not manually taken. It was assumed at that time that the system's temperature data were correct. However, there were several times when the temperature data were very erratic. This condition was later attributed to communication cable problems. Observations were not used when obvious problems existed within the system.

Summary of the Data

The following table shows, for each year, the total number of observations, and how many were usable. Also shown are the number of observations that agreed and disagreed with the system. The accuracy rate shown is the number of agreements expressed as a percentage of the usable observations.

Of the 21 observations discarded in '85-86, ten were because of missing information on the observer's report and 11 because there was no stored data on the system disk. Of the 10 observations discarded in '86-87, two were because of missing information on the observer's report and eight were due to problems with the communication cable or telephone line. These problems are documented on the Maintenance Record in the Appendix.

Data Summary

Observations	Winter		
	84-85	85-86	86-87
Total Number of Observations	34	331	207
Total Usable Observations	34	310	197
Number of Agreements	22	261	173
Number of Disagreements	12	49	24
Accuracy Rate (Percent)	64.7	84.2	87.8

The conditions used to determine agreement or disagreement are considered to be a strict test of the system, particularly when damp conditions are considered. Damp, non-hazardous conditions accounted for 49 of the 85 disagreements over the three winters. The system is capable of detecting very light moisture conditions that may be undetected by a human observer. This normally would result in an alarm being displayed when it was not necessary. This condition occurred three times the first winter, 14 times the second winter, and 9 times the third winter. Ten of the disagreements were due to the precipitation sensor not detecting light snowfall or blowing snow. Generally these disagreements are not critical. (Addition of a snow depth sensor would provide an additional check for snow since it would indicate when snow accumulations of 5 mm or more occur.)

Observations of the Data and System

There is no record of visual observations in the month of December 1985 because of a breakdown of the established reporting system within the road commission. This would have been an excellent month for data collection because it proved to be a month with considerable hazardous weather. This was one of the major reasons for extending the evaluation to the winter of 1986-87.

Accuracy rates were calculated for all three winters. There was a significant difference between the first winter and the last two winters. However, there was also a significant difference in the number of observations made in the three winters. The winter of 1984-85 had only a total of 34 observations, whereas the winters of '85-86 and '86-87 had 310 and 207 observations, respectively. When dealing with random samples, such as these observations, the reliability of the sample increases with an increase in the size of the sample. Although the observations were not totally random, it was sufficient to make the data from the final two winters more reliable than the first.

The data show four visual observations over the first year that reported slippery conditions, the system detected one of these immediately and one about 20 minutes after the observation. The second year there were a total of five observed slippery conditions. The system correctly identified two of them. The third winter there were two observed slippery conditions with one correctly being identified. During the first winter all of the observed slippery conditions occurred during a snow storm when the alarms were cycling on and off. All the slippery conditions observed the second winter were the result of frost or ice. The third winter both observations occurred during snow showers. Although these are a very small percentage of the total number of observations they are mentioned specifically because they are of the greatest concern.

Historical data are stored on a hard disk and this requires periodic checking to make sure the data are being put on it. The data for the month of January 1987 were not on the disk when it was checked for the evaluation report; however, as noted previously, Oakland County had requested the observers to write the system output on their report so data for this month were available. All data are now being backed up on a floppy disk.

The logic circuitry in this sytem will automatically turn alarm 3 on whenever precipitation stops and the road surface is below freezing (see Appendix "Alarms" A3b). This is done because of the European origin of the system. European countries use a much finer grade of salt than our rock salt. It is, therefore, more easily washed away by precipitation. Thus, whenever precipitation stops and the roadway is at or below freezing it is assumed the salt has been washed away and alarm 3 is automatically turned on.

Another situation that may present some confusion is that short duration alarms may show up on the history graph but never be found on the two-hour history printout. This occurs because the two-hour history printout samples conditions instantaneously every 10 minutes, while the history graph records conditions continuously. Due to space allotment, however, the history graph must write in 10-minute increments. Therefore, if an alarm were on for six minutes and that six minutes was between the two 10-minute instantaneous samples for the two-hour history printout, it would not show up on that printout. It would, however, be recorded on the history graph as a six-minute alarm.

It is significant to note that there have not been any multiple car accidents since the system was installed. Other improvements to the bridge also have been made during this time. They include texturizing and aluminum railing removal in 1984 and a latex overlay in 1985. It is, therefore, difficult to say the system was solely responsible for this accident reduction but it probably played a part in it. Also, Oakland County usually checked the bridge whenever alarm 2 came on and salted before a problem developed.

Summary and Recommendations

The Oakland County Road Commission was the agency responsible for operating the system on a day-to-day basis and for maintaining the section of roadway which the system monitored. They also were responsible for requesting service when the system needed repair.

Oakland County personnel feel they have always received excellent service when it was necessary to call for repairs to the system. Due to some misunderstandings, the State's experience was, at first, somewhat different in getting responses from the company. However, since each agency's responsibilities were better outlined there have been no further communication problems.

Oakland County personnel feel that the system has been a valuable asset to them. They have been able to use the system as a tool to predict what may be happening at other locations based on the data received from this location. They would like to keep ice detection in place on this bridge and feel it would be useful at several other locations.

There are five conditions the system senses. To have agreement between the observer and the system it was necessary that the observer and the system agree on all of these conditions. Considering the number of conditions which the observer and system had to agree on, the fact that accuracy rates for the second and third winters were as high as they were was very good. Although some slippery conditions were missed, the system can only sample a very small area of the bridge and must rely on the conditions at that spot. This is the case with all such systems.

There are several recommended changes. First, the automatic turn on of alarm 3 when precipitation stops falling on a roadway at or below freezing is not applicable to the situation in this country and seems to be very confusing. This condition should be addressed in the programmable alarm area. Second, although the short duration alarms mentioned in the "Observations" section are not considered a problem, the software probably should be changed so the alarms either show up in both reports or neither report. A delay could be incorporated to reject all alarms of three minutes or less and if greater than three minutes would be reported as a 10-minute alarm on the two-hour history report.

Finally, the goal of most winter maintenance programs is to provide a safe roadway while using as few resources as possible. Ice detection systems must be considered a tool to help achieve this balance. They are not infallible but they can provide maintenance personnel with valuable data about the road surface and atmospheric conditions. Certainly they cannot be put everywhere. The most benefit would be achieved on bridges that have a proportionally high number of slippery roadway accidents or bridges that are particularly remote from maintenance garages.

APPENDIX

A. System Diagram.

B. Sample of Observation Recording Form.

C. Sample of Completed Visual Observation Form.

D. Sample of present conditions (first two lines of data), and the two-hour history printout for each measuring station. These Correspond to the first visual observation on the previous page.

E. Sample of the same information as described above, but corresponding to the second visual observation.

F1&2. Sample of the 24-hour history graph for the two measuring stations. F1 is for the upper bridge or I 696 and F2 is for the lower bridge or I 275. These 24-hour periods also correspond to the visual observations.

G. Functioning of Alarms.

H. Conditions for Agreement or Disagreement.

I. Distribution of Observations by Month.

J. Distribution of Observations Agreeing with System.

K. Distribution of Observations Disagreeing with System.

L. Maintenance Record.

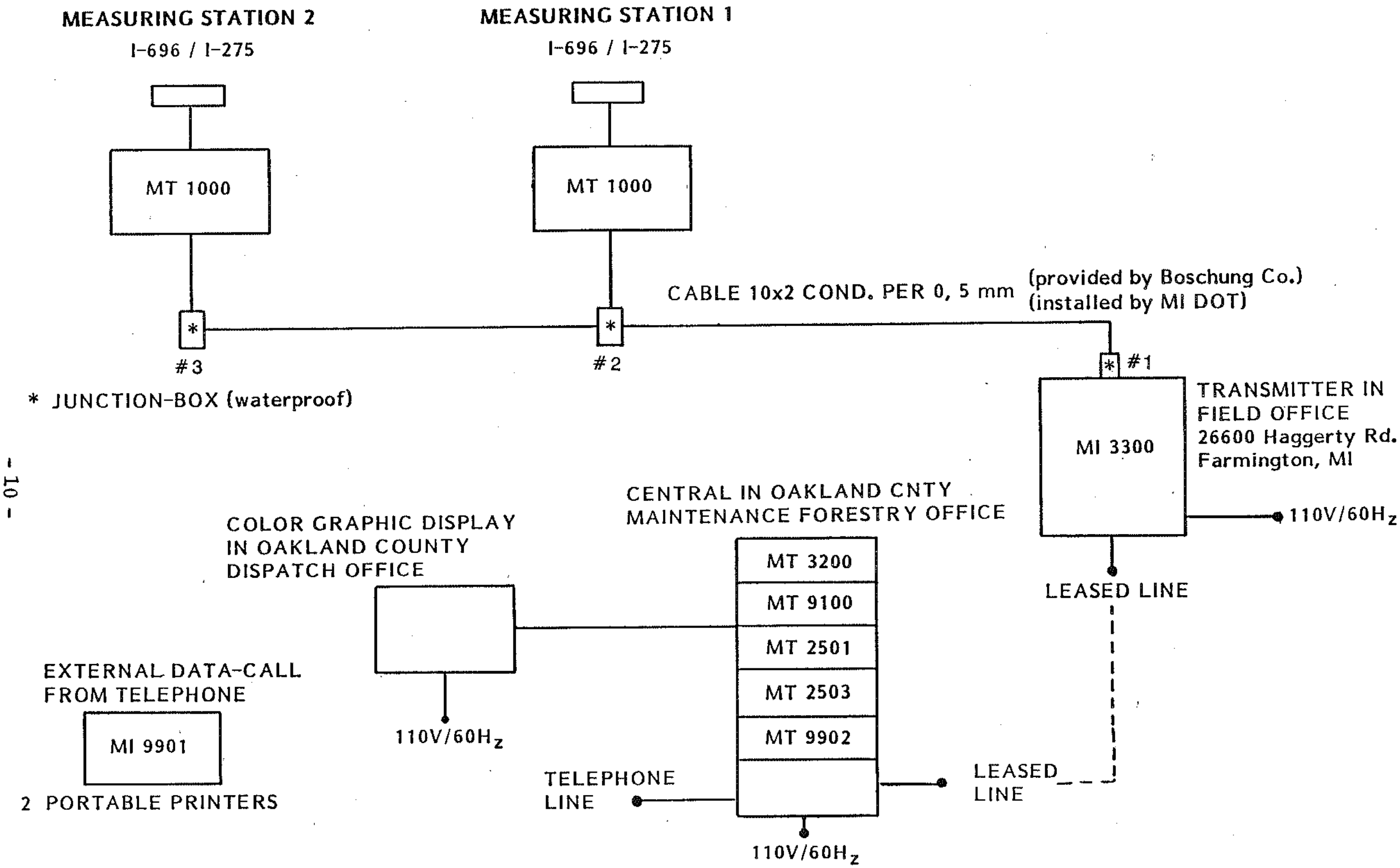

MEASURING STATION 2
I-696 / I-275
MT 1000
MEASURING STATION 1
I-696 / I-275
MT 1000
CABLE 10x2 COND. PER 0, 5 mm
(provided by Boschung Co.)
(installed by MI DOT)
#3
#2
#1
* JUNCTION-BOX (waterproof)
MI 3300
TRANSMITTER IN
FIELD OFFICE
26600 Haggerty Rd.
Farmington, MI
110V/60Hz
LEASED LINE
CENTRAL IN OAKLAND CNTY
MAINTENANCE FORESTRY OFFICE
MT 3200
MT 9100
MT 2501
MT 2503
MT 9902
COLOR GRAPHIC DISPLAY
IN OAKLAND COUNTY
DISPATCH OFFICE
110V/60Hz
TELEPHONE
LINE
LEASED
LINE
110V/60Hz
EXTERNAL DATA-CALL
FROM TELEPHONE
MI 9901
2 PORTABLE PRINTERS

Figure A

PAVEMENT SURFACE CONDITION

Name of Observer:				Date:	Time: a.m. p.m.
WB I696-SB I-275		NB I275-WB I96		Road Surface Condition ( )	
In Wheel Track	Between Wheels	In Wheel Track	Between Wheels		
				Dry	
				Damp (no standing water)	
				Wet (rain or melted snow)	
				Frost	
				Snow	
				Icy patches	
				Ice covered	

Remarks: ______________________________

____

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Figure B

PAVEMENT SURFACE CONDITION

Name of Observer: MARK BUCKBERRY				Date: 12/3/86	Time: 12:40 a.m. (circled) p.m.
WB I696-SB I-275		NB I275-WB I96		Road Surface Condition ( )	
In Wheel Track	Between Wheels	In Wheel Track	Between Wheels		
DAMP	DAMP	DAMP	DAMP	Dry	
				Damp (no standing water) ✓	
				Wet (rain or melted snow)	
				Frost	
				Snow	
				Icy patches	
				Ice covered	

Remarks: ______________________________

PAVEMENT SURFACE CONDITION

Name of Observer: MARK BUCKBERRY				Date: 12/3/86	Time: 5:00 a.m. (circled) p.m.
WB I696-SB I-275		NB I275-WB I96		Road Surface Condition ( )	
In Wheel Track	Between Wheels	In Wheel Track	Between Wheels		
WET	WET	WET	WET	Dry	
				Damp (no standing water) ✓	
				Wet (rain or melted snow) ✓	
				Frost	
				Snow	
				Icy patches	
				Ice covered	

Remarks: ______________________________

Figure C

```
707

? Dial: 3330767

-500
-600
ICE EARLY WARNING SYSTEM          OAKLAND                                  12-03-1986/ 0:40a
MEASURING POINT   AIR DATAS                        GROUND DATAS                WARNINGS
                  TA      DTA    P   SD            TG       DTG   W             1 2 3 M S D
I-696              38.5    00    N    0.0           38.8     00   Y
I-275              39.2    00    N    0.0           39.2     00   Y
-------------------------------------------------------------------------------------------

-501
ICE EARLY WARNING SYSTEM          OAKLAND    /I-696                        12-03-1986/ 0:40a
MEASURING POINT   AIR DATAS                        GROUND DATAS                WARNINGS
                  TA      DTA    P   SD            TG       DTG   W             1 2 3 M S D
 0                 38.5    06    N    0.0           38.8     00   Y
-10                38.5    00    N    0.0           38.8     00   Y
-20                38.5    00    N    0.0           38.8     00   Y
-30                38.8    00    N    0.0           39.2     06   Y
-40                38.8    00    N    0.0           38.8    -06   Y
-50                39.2    06    N    0.0           39.2     06   Y
-60                39.2    06    N    0.0           39.2     06   Y
-70                39.2    06    N    0.0           39.2     00   Y
-80                39.2    06    N    0.0           39.2     00   Y
-90                39.2    06    N    0.0           39.2     06   Y
-100               39.2    06    N    0.0           39.2     00   Y
-110               39.2    06    Y    0.0           39.2     00   Y
-120               39.2    06    Y    0.0           39.2     00   Y
-------------------------------------------------------------------------------------------

-502
ICE EARLY WARNING SYSTEM          OAKLAND    /I-275                        12-03-1986/ 0:42a
MEASURING POINT   AIR DATAS                        GROUND DATAS                WARNINGS
                  TA      DTA    P   SD            TG       DTG   W             1 2 3 M S D
 0                 39.2    00    N    0.0           38.8    -06   Y
-10                39.2    00    N    0.0           39.2     06   Y
-20                39.2    00    N    0.0           39.2     00   Y
-30                39.6    00    N    0.0           39.2     00   Y
-40                39.6    00    N    0.0           39.2     00   Y
-50                39.6    00    N    0.0           39.2     00   Y
-60                39.9    06    N    0.0           39.2     00   Y
-70                39.6    00    N    0.0           39.2    -06   Y
-80                39.9    06    N    0.0           39.2     00   Y
-90                39.9    06    N    0.0           39.2     00   Y
-100               39.6    00    N    0.0           39.2     00   Y
-110               39.9    06    N    0.0           39.2     00   Y
-120               39.9    06    N    0.0           39.2     00   Y
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Figure D

-600

ICE EARLY WARNING SYSTEM   OAKLAND   12-03-1986/ 5:00a

MEASURING POINT	AIR DATAS TA	DTA	P	SD	GROUND DATAS TG	DTG	W	WARNINGS 1 2 3 M S D
I-696	39.2	00	Y	0.0	38.5	-06	Y	
I-275	39.9	00	Y	0.0	39.2	00	Y	

-GOOSEEFEARLY/RAGNENG SYSTEM   12-03-1986/ 5:01a

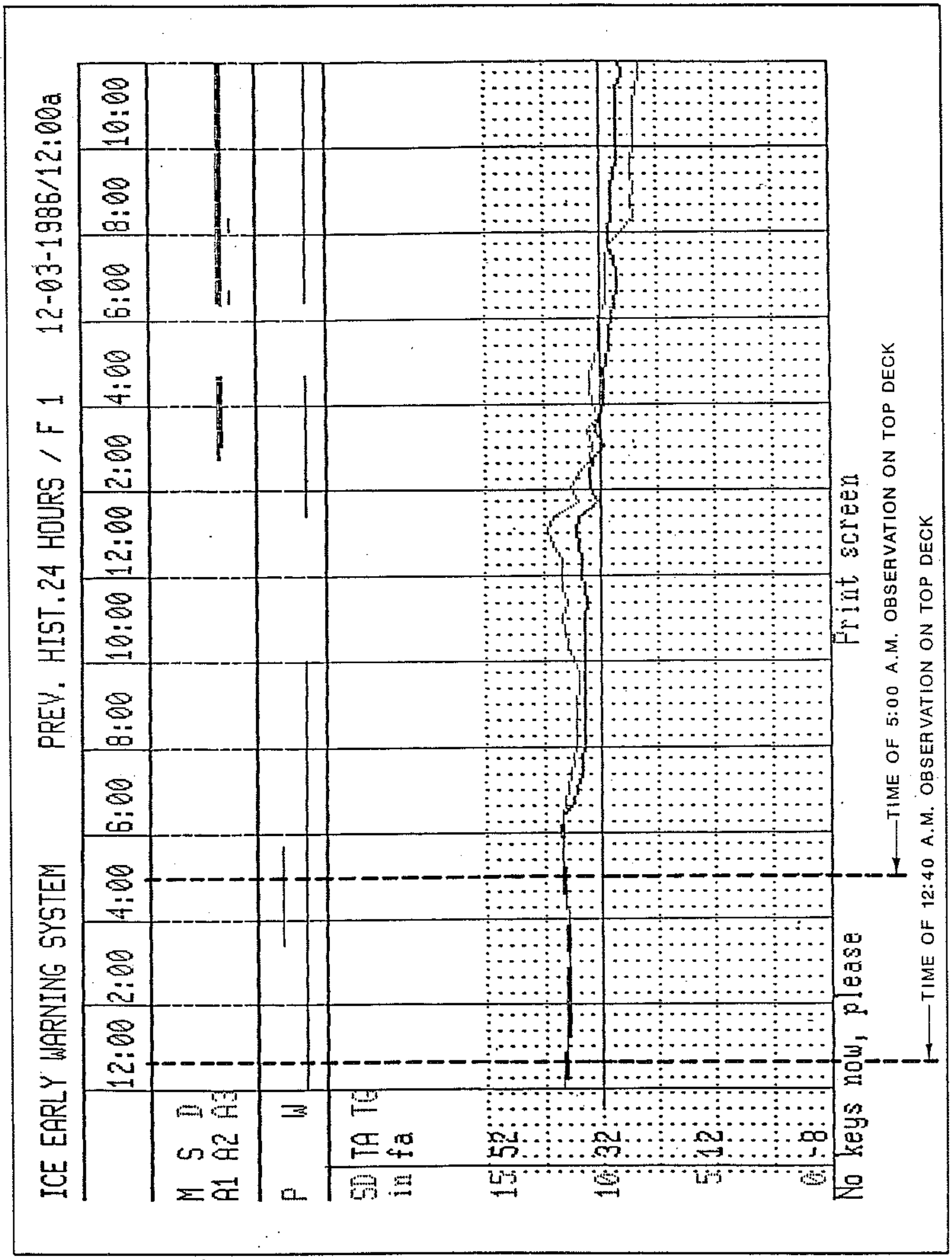
MEASURING POINT	AIR DATAS TA	DTA	P	SD	GROUND DATAS TG	DTG	W	WARNINGS 1 2 3 M S D
0	39.2	00	Y	0.0	38.5	-06	Y	
-10	39.2	00	Y	0.0	38.8	00	Y	
-20	38.8	00	Y	0.0	38.5	00	Y	
-30	38.8	06	Y	0.0	38.5	00	Y	
-40	38.5	00	Y	0.0	38.5	06	Y	
-50	38.5	00	Y	0.0	38.1	00	Y	
-60	38.1	00	Y	0.0	38.1	-05	Y	
-70	38.1	00	Y	0.0	38.5	00	Y	
-80	38.1	00	Y	0.0	38.5	00	Y	
-90	38.5	00	N	0.0	38.1	00	Y	
-100	38.1	00	N	0.0	38.5	00	Y	
-110	38.1	00	N	0.0	38.1	00	Y	
-120	38.1	00	N	0.0	38.1	-05	Y	

-602

ICE EARLY WARNING SYSTEM   OAKLAND   /I-275   12-03-1986/ 5:02a

MEASURING POINT	AIR DATAS TA	DTA	P	SD	GROUND DATAS TG	DTG	W	WARNINGS 1 2 3 M S D
0	39.9	00	Y	0.0	39.2	00	Y	
-10	39.9	00	Y	0.0	39.2	00	Y	
-20	39.9	06	Y	0.0	39.2	06	Y	
-30	39.6	00	Y	0.0	38.8	00	Y	
-40	39.2	00	Y	0.0	38.8	00	Y	
-50	39.2	00	Y	0.0	38.8	00	Y	
-60	39.2	00	Y	0.0	38.8	00	Y	
-70	39.2	00	Y	0.0	38.8	00	Y	
-80	38.8	00	Y	0.0	38.8	00	Y	
-90	39.2	00	Y	0.0	38.8	00	Y	
-100	39.2	00	N	0.0	38.8	00	Y	
-110	38.8	00	N	0.0	38.8	00	Y	
-120	38.8	00	N	0.0	38.8	00	Y	

Figure E



ICE EARLY WARNING SYSTEM
PREV. HIST.24 HOURS / F 1
12-03-1986/12:00a
12:00 2:00 4:00 6:00 8:00 10:00 12:00 2:00 4:00 6:00 8:00 10:00
M S D
A1 A2 A3
P W
SD TA TG
in fa
15 52
10 32
5 12
0 -8
No keys now, please
Print screen
TIME OF 5:00 A.M. OBSERVATION ON TOP DECK
TIME OF 12:40 A.M. OBSERVATION ON TOP DECK

Figure F1

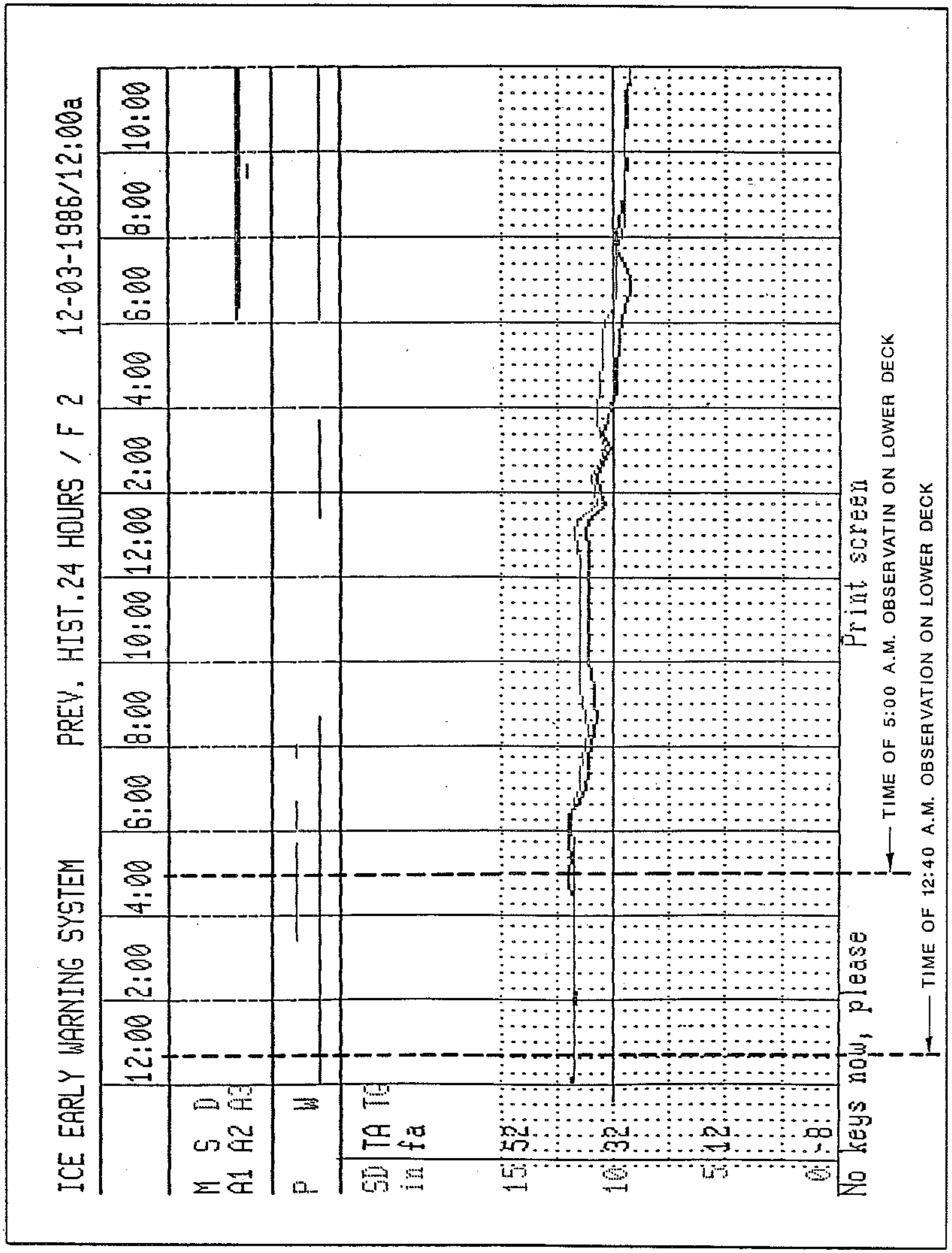

ICE EARLY WARNING SYSTEM
PREV. HIST.24 HOURS / F 2
12-03-1986/12:00a
12:00
2:00
4:00
6:00
8:00
10:00
12:00
2:00
4:00
6:00
8:00
10:00
M S D
A1 A2 A3
P W
SD TA TC
in fa
15 52
10 32
5 12
0 -8
No keys now, please
Print screen
TIME OF 5:00 A.M. OBSERVATIN ON LOWER DECK
TIME OF 12:40 A.M. OBSERVATION ON LOWER DECK

Figure F2

FUNCTIONING OF ALARMS

A1 Ground temperature or air temperature less than 32 F and wet.

A2 a) Surface temperature less than 35.6 F and wet (means ice on artificially cooled sensor).

b) Surface temperature less than 32 F and wet and precipitation (no salt).

c) Surface temperature less than 32 F and no precipitation and wet - changed from No to Yes (frost on artificially cooled sensor).

A3 a) Surface temperature less than 32 F and wet and ice on sensor No. 1 (ice on road).

b) Surface temperature less than 32 F and wet and precipitation change from Yes to No.

M Programmable alarms that can be programmed to turn-on whenever a given set of conditions occur (not used in this study).

S Snow depth alarm (not used in this study because the installation doesn't have a snow depth sensor).

D Disturbance alarm (power or communication failure).

Figure G

Conditions for Agreement or Disagreement

The visual observation and the system were determined to agree if all the conditions the observer noted agreed with what the system was displaying on the terminal or had stored on disk. For example, if the system was not displaying any alarms, showed no moisture on the deck, there was no precipitation falling, the observer noted the road surface to be "dry" and made no comment as to there being any precipitation falling the two were determined to agree.

The visual observation and the system were determined to disagree if any of the conditions noted by the observer disagreed with what the system was displaying or had stored for that time. The two were also determined to disagree if the observer made a special note of a particular condition. For example, if the system had only turned alarm 1 on and the observer noted the roadway was slippery and alarm 3 should have been turned on the two were determined not to agree.

Figure H

Distribution of Observations by Month

Winter	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
84-85				6	22	6	
85-86		55	0	57	94	96	8
86-87	48	56	40	29			

Figure I

Distribution of Agreements

Conditions	Winter		
	84-85	85-86	86-87
No Alarm, Dry	11	185	115
No Alarm, Wet or Damp	10	48	25
Alarm 1, Wet or Damp	0	19	21
Alarm 1 & 2, Wet or Damp	0	7	11
Alarm 1,2,3, Snow or Ice	1	2	1
Total	22	261	173

Figure J

Distribution of Disagreements

System	Observer	Number of Times Occurred		
		84-85	85-86	86-87
No alarms, no moisture, no precipitation	Damp		7	2
No alarms, no moisture, no precipitation	Wet		2	
No alarms, no moisture, no precipitation	Damp (slippery - had to salt)		2	
Precipitation, no alarms, no moisture	Dry (no precipitation)		1	
Precipitation, no alarms, no moisture	Wet		2	
Moisture, no alarms, no precipitation	Dry		1	6
Moisture, no alarms, no precipitation	Damp (snowing)		2	1
Moisture, precipitation, no alarms	Dry		1	
Moisture, precipitation, no alarms	Damp (no precipitation)	2	1	
Moisture, precipitation, no alarms	Frost (slippery)		1	
Moisture, no precipitation, no alarms	Wet (raining)		1	
Alarm 1, moisture, no precipitation	Dry	2	3	2
Alarm 1, moisture, no precipitation	Dry (blowing snow)			1
Alarm 1, moisture, no precipitation	Snow		1	
Alarm 1, moisture, no precipitation	Wet (snowing)		1	2
Alarm 1, moisture, no precipitation	Dry (air & deck both above 32 F)		1	
Alarm 1, moisture, precipitation	Damp (not snowing)	1		
Alarm 1, moisture, precipitation	Snow (Slippery, should be alarm 3)	3*		
Alarm 1, 2, moisture, no precipitation	Dry	1	3	1
Alarm 1, 2, moisture, no precipitation	Damp (snowing)			1
Alarm 1, 2, moisture, precipitation	Icy patches (should be alarm 3)		2	
Alarm 1, 2, moisture, no precipitation	Snow (had to salt)			1
Alarm 1, 2, 3, moisture, no precipitation	Damp (not slippery)		4	
Alarm 1, 2, 3, moisture, no precipitation	Dry	3	8	
Alarm 1, 2, 3, moisture, precipitation	Damp (not slippery)		3	
Alarm 1, 2, 3, moisture, no precipitation	Wet or Damp (not slippery)		1	7
Alarm 1, 2, 3, moisture, no precipitation	Wet (snowing)		1	
Total		12	49	24

*One of these was picked up by the system 20 minutes after the observation was made.

Figure K

Maintenance Record

During the winter of 1986-87 the Boschung Co. was asked to log all maintenance work done on the system. The following are the log entries:

10-2-86	Starting up of the system.
10-16, 17	Installed printer and removed it due to system malfunction.
10-26	We told them to shut off the system for 1 hour to compensate for time change.
11-02-86	Disturbance from 8 a.m. until 5 p.m. because of defective telephone line.
12-05-86	Approx. 10:30 a.m., backing up the data.
12-05-86	Approx. 3:30 p.m., disturbance until 12-12-86 at 7 p.m. Reason for the disturbance was the leased telephone line. M. Boschung went to Pontiac on 12-12 in order to work with Bell Co.
12-22-86	Boschung performs a complete check of AMS F2. The air temperature seems to be unstable. Between approx. 1:30 p.m. until 5 p.m., we checked booth AMS with a simulator.
01-05-87	Disturbance started approx. 5 p.m. until approx. 12:30 p.m. 1-7-87. Reason for disburbance was the leased telephone line.
01-13-87	M. Boschung exchanged TL & TI boards at AMS F2. Frank Spica was there too.
01-15-87	M. Strobel started to repair AMS F2 approx. at 2:30 p.m. On 01-17-87, he finally found the problem to be a short in the cable between the AMS and the field office.

Figure L