Anti-Icing on Structures Using Fixed Automated Spray Technology (FAST)

Demonstration Project, Prescott Ontario

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Overview

This paper overviews the selection, design, implementation and performance of Canada's first fixed automated anti-icing spray system installation for a highway/roadway application. Installed in the fall of 2000 on the northbound 416/401-interchange structure, the system has been in service for the entire winter of 2000/2001.

The construction of this new bridge was completed in September of 1999. During the first winter of operation a number of weather related accidents occurred on the structure. For a number of years the Ministry of Transportation, Ontario (MTO) has been investigating anti-icing and (Advanced) Road Weather Information Systems ((A)RWIS) as independent approaches and systems to complement the established levels of service for roads during winter storms.

Based on its own research and the experience of other agencies, MTO believed that there was an opportunity to significantly reduce the potential for icing on the structure. This could be achieved by
remotely sensing potential frost and ice and automatically applying a liquid deicing chemical before it actually formed. The FAST system continuously monitors conditions on the structure and based on the detection of critical threshold parameters it automatically sprays the chemical just in advance of icing conditions. The structure in question is a 165m super-elevated, high speed, freeway-to-freeway ramp with a design speed of 130km/hr and a 3000 AADT. Since putting the system into service there have been no weather related accidents.

The Ministry and its maintenance contractor have also taken this opportunity to evaluate the performance of Liquid Potassium Acetate. This chemical is not on Environment Canada’s list of road deicing chemicals which are under consideration to be designated as "toxic" under Section 64 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

This report reviews the FAST installation at the site, the roles of the partners in the implementation and operation; how a desire for enhanced response time, increased safety, and reduced environmental impact, resulted in study and implementation within a 6 month time period; project costs; approach to study, design, procurement, contracting and risk sharing; lessons learned during design and through the operation to date and other relevant points which maybe of interest to road authorities.

**Objective**

For number of years the Ministry of Transportation, Ontario (MTO) has been investigating Anti-Icing and (Advanced) Road Weather Information Systems ((A)RWIS) as independent approaches and systems to maintain the established levels of service for roads during winter storms and to improve road safety.

MTO, based on their own research and the experience of other road agencies, believed that there was an opportunity to significantly reduce the potential for icing on the Highway 401/416 interchange northbound structure (see figure 1). This could be achieved by remotely sensing potential frost and ice using an ARWIS and automatically applying a liquid deicing chemical before it actually formed. The Fixed Automated Spray Technology (FAST) system continuously monitors conditions at the structure and based on the detection of critical threshold parameters automatically fires, spraying the chemical just in advance of icing conditions. The selected spray system was required to effectively apply the liquid to the driving surface under a range of weather conditions and depending, on how the programmable logic was configured, continue to monitor conditions and automatically either repeatedly reapply the anti-icing chemical if the chemical becomes diluted or, deactivating the program in the event of a heavy snowfall. Deactivation is required since FAST system was intended as an anti icing system, not a snow removal system.

**Process**
During the first winter of operation, the northbound 416/401-interchange structure a number of weather-related accidents occurred on the structure. In reviewing the nature of the problem it became apparent that there existed a combination of factors at the site which presented a challenge for the maintainers and which made it worthy of note:

- The structure, although relatively new, had already developed a history for accidents.
- The structure carried a volume of 3000 AADT and was a key route to the Nations' Capital.
- The structure is a high-speed ramp on a rural freeway.
- The alignment of the structure and topography meant the prevailing winds were at most times running across the deck.
- The location was remote from the dispatch location and not in the same micro climactic zone.
- The structure was prone to icing earlier and more often than the interconnecting segments.

MTO felt that the problem warranted a unique solution which included automated detection and chemical application and began conversations with a variety of agencies and vendors regarding the suitability of the structure for installation of a FAST system.

Mark F. Pinet & Associates Limited (MFPA) an Eastern Ontario consulting engineering firm with extensive Advanced Road Weather Information System (ARWIS)/Road Weather Information System (RWIS) experience was retained by the Ministry of Transportation, Ontario (MTO) to complete a feasibility study, Request for (vendor) Information (RFI) and Request for (contractor) Proposal (RFP) relating to the purchase and implementation of a FAST system at the site. Following the procurement approval, MFPA was retained by Cruickshank Construction to complete the design, installation and commissioning of the fully automated "Boschung" FAST System. The system was installed in September of 2000 and the commissioning of the final components was completed on mid October 2000.

Cruickshank Construction has been employing the system to service the structure during the winter of 2000/2001 and MTO has been supplying the deicing chemical under the Area Maintenance Contract. Mark F. Pinet & Associates Limited has been retained by the Ministry to provide support and technical services relating to the on going service and performance monitoring of the system through the winter to ensure that the system operates as intended. As part of that assignment MFPA is also required to prepare this summary report which describes the process and the system as installed.

**Description and Design**

**Description Of The Location And Structure**

Highway 401 through this section is a four lane rural freeway constituting the main commercial truck and passenger route between Toronto and Montreal. Highway 416 is also a four lane rural freeway carrying traffic to and from Highway 401 and Ottawa. The junction of the two highways occurs near Prescott between Cornwall and Brockville. The site has a micro-climate, which is subject to "lake effect storms" from the St. Lawrence River which is in close proximity and south of the site.

The structure is a 165 meter long, 11.2 m wide, super-elevated, concrete, high speed, freeway-to-freeway ramp with a design speed of 130km/hr and 3000 AADT on one single lane in the northbound direction. The structure features a paved deck with a shoulder inside and outside of the 4.75 meter wide through lane.

**Description of Fixed Automated Spray Technology (FAST) System**

Fixed Automated Spray Technology (FAST) involves the sensing of pending frost and ice and the preemptive, automated spray application of liquid anti-icing chemicals. The ministry's objective was to
have the system's technology accurately predict the road surface temperature and icing conditions based on
detection by the system and the system automatically spray the deicing chemical, immediately in advance
of icing conditions. In order to meet this objective the FAST system would be made up of three
subsystems:

- The RWIS Detection and Activation System
- The Hydraulic System, and
- The FAST System Server.

Through research by MFPA, it was determined that all the vendors sell systems which are fixed and will
spray the desired surfaces, however the range of options to activate and the degree and accuracy of
detection is diverse. The level of sophistication also has a significant affect on the overall cost of the
system and installation. The range of automation options available includes:

- Manual detection and activation on site using patrols
- Automated detection at the site, remotely alarmed and manual, on site activation
- Automated detection at the site, remotely alarmed and manual, remote activation
- Automated detection and activation at the site based on programmable logic complete with
  continuous recording of data relating to atmospheric and pavement conditions as well as system
  hydraulic operations

As a result of discussions with the Ministry staff it was agreed that only the combination of last two
options was acceptable to meet the Ministry's objectives identified at the outset of the project
notwithstanding there was a significantly higher cost for the system purchase and implementation.

In order to meet the detection and activation specifications the vendors relied on demonstrated RWIS
technology. During the implementation phase it was agreed that providing the balance of the equipment
required to make the system a full RWIS station could further extend the benefit of the FAST system. The
incremental cost for this improvement was approximately 5% of the system cost. With this change it will
be possible to extrapolate the observed site conditions to other similar locations, in the same micro
climactic zone following data assimilation and based on expert interpretation or modeling.

The Ministry has been investigating the use of a variety of chemicals and chemical mixtures to maintain
the prescribed level of service and enhance safety for the motoring public in all weather conditions while
reducing the cost of application, reducing environmental impact and extending the life-cycle of the
infrastructure. The uncertainty over the type of deicing chemical, or mixture of chemicals applied or
carried onto the structure by vehicles is a significant, but an inevitable problem. Despite this, it is
imperative that the detection system accurately predicts the freeze point of the solution on the structure;
otherwise it becomes a reactive deicing system instead of a proactive anti-icing system. The consequence
of inaccurately predicting pending freezing conditions either means excessive and unwarranted use of
chemical or potentially increasing the driving hazard by making the conditions worse than they otherwise
would be by applying a deicing chemical and then having it refreeze. To date only active pavement sensor
technology, which freezes a sample of the pavement surface (verses passive which measures conductance)
is able to accurately predict the freeze point of a chemical mixture, of varying relative concentration. The
incorporation of active sensors has however introduced different technical issues from those encountered
for passive sensors as a result of the new requirement to power the pavement sensor, which results in
slightly higher costs for system purchase.

The ARWIS Detection and Activation System

The Detection /Activation system components include:

- Pavement sensors
Road Condition (Pavement) Sensors

In a FAST system installation, the pavement sensors should have the following characteristics:

- Ability to measure or detect the following condition data:
  - Pavement surface temperatures (measured)
  - Subsurface temperature (measured)
  - Moisture- dry, moist, or chemical wet (detect)
  - Ice, snow, frost conditions (detect)
  - Concentration of residual chemicals and/or anti-icing agents (detect/measure)
  - Freeze point detection for each of the following potential liquid deicing chemicals:
    - Sodium Chloride (Salt)
    - Calcium Chloride
    - Magnesium Chloride
    - Magnesium Acetate
    - Potassium Acetate and Mixtures thereof.
  - Demonstrate a high degree of sensitivity at the two important temperature thresholds (freezing point with no deicing chemical present) and the freeze point where the deicing chemical fails to be effective even at high concentrations (approximately -20 degrees Celsius).

- The vendor was required to specify the number and location of the sensors to ensure adequate and accurate detection of critical conditions required to trigger the initial and subsequent anti-icing/deicing spray applications.

The Pavement Sensor itself must:

- Have thermal conductance similar to the road surface
- Be either thermally passive (no heating or cooling) or thermally active (artificially heating or cooling) as required to meet all of the specifications above
- Be similar colour and have solar reflectivity characteristics similar to the road surface;
- Have wear characteristics similar to the road surface
- Be supplied:
  - With a sufficient length of cable and extension cable as required.
  - With Splice Kits and Sealants
  - So as not to require penetration of the bridge deck/or waterproofing membrane

Atmospheric Weather Sensors (Full RWIS alternative)

Atmospheric sensors are to address the following:

- Air temperature;
Wind speed and direction (measured);
Precipitation (detection);
Relative humidity (measured);
Dew Point (calculated);
Measure data at World Meteorological Organization (WMO) regulation height;
Must be either tolerant to salt or other chemicals or located so as not to be adversely affected by the spray from vehicles.

Remote Processing, Data Logger Unit (RPU)

In a FAST installation, the remote processing unit should:
- Collect and store a minimum of 24 hours of data from the road condition sensors and atmospheric weather sensors for transmission to the FAST Data Server via Modem. Data is recorded against the real time for performance review, at a later date;
- Trigger the spray system, based on observations from the detection system;
- Select and initiate an appropriate spray program in response to the specific observed condition;
- Temporally activate or disable the spray system according to the operating logic, manually on site or remotely via dial up modem;
- Be designed based on an "Open System Architecture" to facilitate integrating additional sensors (i.e., pavement condition, meteorological, traffic counters, loop detectors, video cameras) and outputs (e.g. message signs) to be added.

FAST Data Server

The Fast Data Server:
- Is the data warehouse and communication hub for the FAST System;
- For security reasons, it is located offsite from the FAST RPU;
- The system often is connected to the clients network in order that the data can be backed up;
- The server dials out to the FAST site on a regular interval, retrieves and archives the RPU atmospheric, pavement condition and FAST hydraulic system data;
- The system users access the data from the server via dial up or network connections and employ proprietary vendor software to view the data in a graphical and tabular format;
- Allows the monitoring of the FAST system operation, system administration, software upgrades, debugging and diagnostics remotely via modem; and
- The server restricts user privileges as dictated by the system administrator to allow users a full range of options from read only privileges all the way up to remote operation of the system and remote adjustment of system operating parameters.

Remote User Interface Software

The Vendors proprietary software can be used to view existing conditions, archived data, and a 24-hour operating history. Depending on the assigned user privileges it may be used to operate the system.

FAST Hydraulic System

The Fast Hydraulic subsystems consist of:
- Pump station;
- Nozzles;
Hydraulic Piping and Control wiring;
- Valve Boxes.

Pump Station

A pump house was constructed at the site to enclose all the required mechanical, power, communication and monitoring equipment required for the proper functioning of the spray system. In addition to the structure, a chain link security fence was provided to secure the installation.

Within the pump house the following components are found:
- Pump station
  - Pump;
  - Chemical reservoir;
  - Control valves;
  - Filters;
  - Relays;
  - Reservoir level sensors;
- Power supply equipment;
- Communications drops.

The vendor provided the complete pump station as a stand-alone package consisting of pumps, valves, metering devices, connections, controls, sensors, and storage tank. Separate panels for the electrical distribution and the pump station controller are also located in the pump house.

The pump controls are located in the pump house and contain the high power switches and relays, which switch the pump on and off and monitor the relevant levels and pressures.

The system may be activated from a number of sources: remotely, from a page; on site, manually (switch on the outside of the barrier wall at the west side of the north abutment); or automatically, based on certain atmospheric and/or pavement conditions which are observed by the ARWIS (AMS) RPU station from the atmospheric and/or pavement sensors.

Spray Nozzles

The Spray nozzles were originally specified as parapet style, side mount nozzles so as to minimize the impact on the existing structure. It was later determined that a flush mount nozzle embedded in the pavement would require less damage to the structure. The obligation to provide and specify a sufficient number of spray nozzles was transferred to the vendor to assure adequate coverage of critical locations for initial and subsequent spray applications. The nozzles were directionally adjustable in all three axes and were installed in advance of the structure, at the direction of the vendor, to ensure that the deicing chemical would be tracked onto the structure. The spray nozzles specified are resistant to severe environmental conditions such as salt and other chemicals. The materials and accessories provided by the vendor consist of: nozzles, epoxy, sealant, mounting and adjustment hardware.

Mechanical Distribution Piping

The vendor was required to provide pipes, pressure fittings, valves, reservoirs and control wirings and mounting brackets. These conduits, fittings and accessories are resistant to severe corrosive environment conditions such as salt and other deicing chemicals. The flexible piping supplied by the vendor is manufactured specifically for the application. The flexible plastic tubing makes it easier to work with for the installation; ensures corrosion resistance and allows for a limited range of movement from frost action,
or as a result of accident impact. Stainless steel mechanical connectors were easy to work with and resist corrosion.

Valves

Sufficient manual valves were installed to allow for partial system operation in the event of accidental impact damage. Solenoid actuated stainless steel valves allowing control of liquid to the spray nozzles controlled valves between distribution piping and lateral branches were employed.

FAST System Controller

The pump station controller is located in the pump house and controls both pump and valve operation. The system will on a regular basis perform a self-diagnostic test to confirm the system is ready to spray the deicing chemical. In the event that the system detects a fault, it issues an alarm at the pump house, which is relayed to the RWIS RPU and is picked up by the server and identified as an alarm on the server and then to the user terminal. In the event of an alarm it must be determined the nature of the fault and the situation remedied before the FAST will spray automatically again and depending on the nature of the fault (e.g. low chemical level or loss of pressure) may not allow the system to fire at all.

Research and Procurement

Literature relating to experiences with FAST systems was reviewed from a variety of road winter maintenance organizations in the United States. A list of potential vendors was developed and a number were requested to provide technical literature and brochures outlining system principles, specifications and features of their respective systems. A request for information (RFI) was then prepared which outlined the general scope of work and ensuring enough information was provided to have the vendors prepare a cost estimate for supply of the system and the limited number of services they would be required to perform. The research undertaken provided background for the feasibility study, which was intended to identify the system vendors as well as the available and currently employed systems. The report also drew conclusions on which system Vendor, methodology and equipment was best suited for MTO's specific requirements on the subject site, based on the best value for the cost and estimated the cost of the complete system.

Once MTO selected the vendor, MFPA worked with the implementation "Contracting Team” and vendor to develop the necessary instructions, detailed design drawings and specifications; expedited review and approval and then supervised and co-ordinated installation of the FAST system by the Ministry's contractor(s) under the direction of the system vendor. Details of the work plan were coordinated with the vendor, contractor and the Ministry such that qualified knowledgeable staff and/or local contractors were utilized to support and work with the vendor thereby ensuring that their system was installed and operated as intended.

Procurement

Capital funding for the project was provided as part of the rehabilitation of the northbound 416 lanes. The Ministry at the time had two contracts underway, which had boundaries of their work, which covered the subject site. These contracts were for the reconstruction of the northbound 416 and the Area Maintenance Contract (AMC). MFPA re-packaged the RFI as a fixed price request for proposal (RFP) and the Ministry administered the procurement process with the two contractors. Cruickshank Construction was selected as the successful proponent and proposed employing Boschung America as the Vendor. The work was added as an extra to their existing AMC contract.
Risk Sharing, Partnerships with Industry, MTO

The 416/401 FAST Project was completed in the spirit of a demonstration project with all participants assuming some of the risk. MTO needed to deal with a single contracting party, which was responsible for: supplying the equipment and possessed the technical capability to ensure the system would work as intended; could supply system maintenance and service locally; and could meet the ministry high liability insurance requirements.

Since the project was a first in Canada, none of the participants had worked with the Vendor or their systems prior to this project. MFPA was the only participant with any experience with RWIS and sensor installation on bridges. All participants however recognized the potential for the equipment to be used in the future and as such were willing to share some of the risk for the services or equipment for which each of them respectively supplied in the undertaking. All participants supplied equipment and services for which they were not fully compensated with a view of gaining experience and insight into FAST and demonstrating the technology could work to meet the ministry's objectives.

Installation

Design and Project Management

Despite the contracting parties being MTO and Cruickshank it was understood that project manager held much of the responsibility to ensure that the system would perform as anticipated since it was the common thread in the implementation team from the feasibility phase to the commissioning phase. The vendor provided a limited amount of generic engineering design based on standard details. Details of the site, adaptation to the existing structure, pump house, utility services, system architecture and configuration to suite the local application were developed by MFPA. The actual ARWIS instrumentation installation was completed by MFPA. The balance of the work related to the installation of the complete and operational FAST system including all the distribution piping and appurtenance installation was performed under the supervision of the Project consulting engineer, Mark F. Pinet and Associates Limited.

Installation by MTO's Contractor

Cruickshank Construction Limited was selected as the General Contractor for the project and the work was performed as an extension to their existing Area Maintenance Contract. They retained all other members of the implementation team including consultants, contractors, and the vendor. In addition to acting as General Contractor they were responsible for the underground plant for the FAST, the civil works and the Pumphouse construction. Cruickshank also retained a hydraulic contractor; Central Source Irrigation, who possessed substantial experience with similar large scale automated hydraulic systems to complete the mechanical portion of the work.

Installation by the Vendor

The installation works completed by the vendor included; all hardware and software for the RPU; all work not specifically identified as being supplied or installed by the MTO's Contractor; commissioning and burn in testing of the system and all components; pressure testing of the hydraulic system and all components and training.

Budget Estimate and Costs
Boschung America was the preferred vendor based on the value of the performance of the system they proposed for the price. The following outlines the estimated cost for a complete system provided and fully installed at the subject site based on a conceptual design and Boschung as the vendor. The following shows the components for a complete supply and installation of a FAST system.

Original
- Equipment Supply (excl full RWIS)
- Installation*
  - Civil
  - Spray System
  - Gantry System
  - Electrical
- Engineering
- Contingency

**Total Preliminary Budget Cost: $239,000**

Additional Costs
- Upgrade to full ARWIS
- Security fencing
- Chemical supply
- Utility service extensions
- Maintenance
- Changes in Duty and Exchange
- Additional Research

**Total Final Cost: $300,000**

*The original budget was based on MTO retaining all the subcontractors directly without a General Contractor.

The actual construction cost was $300,000. The Fast system coverage is 1784.5 m² on the bridge and 190 m² on the approach to the bridge for a total of 1963 m² or $153/m². Since this is a demonstration project, future costs are expected to be higher. The annual operating cost is approximately $15,000, or $7.64/m² annually excluding annual maintenance of the spray system, pumps and systems.

**Maintenance**
The system should be maintained in accordance with the Vendors suggested procedures.

**Start Up (Fall)**
In the fall the system should be checked and refilled with chemical and the ARWIS station serviced. The entire system should be checked for damage and repaired including replacement of any failed joint sealant etc on the structure.

**Shut Down (Spring)**
In the spring the system must be flushed with clear water and the filters checked/replaced. The system is left pressurized and any change in pressure is flagged as an alarm to the System Administrator. The system should on a regular basis be cycled through using clear water.

In addition, the following recommendations should be taken into account.

- Follow the Vendor's operating manual instructions.
- The contractor will be required to monitor the chemical levels within the pump house and refill the tanks to suit the intensity of the storm.
- The contractor should employ good house keeping practices to ensure the electronics are not damaged by humidity or the presence of the chemicals.
- The contractor should adhere to appropriated health and safety regulations and should have all WHMIS sheets and personal protective equipment at the site for handling chemicals and any necessary safety equipment within the pump house.
- Wiring is a combination of North American and European voltages (120/208/230 volts) and must be fully inspected by the appropriate electrical inspection authority. The maintenance contractor should use caution when working around electrical equipment and appropriate warning signs shall be used.

**Operational Plan**

In order to successfully integrate FAST into the Winter Maintenance Service Provider's toolbox, a plan of operation must be developed to fully integrate the new technology into all the related and affected business processes.

The FAST system was to be operated as outlined in the operating manual supplied by Boschung, the system vendor and as outlined in the user, operator and maintenance training sessions provided by the vendor however it was the responsibility, of the owner, in this case the MTO to:

- Obtain procedural approvals;
- Cause an adjust in maintenance operations under the Area Maintenance Contract;
- Provide training, access and support to gain the confidence of staff in the system;
- Provide access to the FAST system data to those inside and outside MTO requiring it;
- Provide the necessary resources to monitor the performance of the system to ensure that the system is operating as MTO intended i.e. that the system was applying chemical at the appropriate time;
- Provide and understand the logic and timing for the application of the selected anti-icing/deicing liquid chemical;
- Provide the necessary resources to monitor the system operation to ensure that the system is continuously operating in the ready mode and no system alarms have occurred during the self diagnostics testing;
- Select the and appropriate liquid chemical;
- Provide any warning signs to motorists to alert them of the automated anti-icing /deicing operation;
- Pay the operating cost which include, power, telecommunications, and supply of chemicals;
- Indemnify the General Contractor and Subcontractors against future claims except for negligence specifically relating to the installation of the FAST System;
- Ensure the RPU and pump house site is secure from vandalism.

**System Interfacing**

The Vendor's user interface software provides a graphical presentation to the operator, allowing them to control, manage, or observe, the FAST system depending on the users authorized privileges. At the highest level, only Administrators are permitted to modify FAST system critical threshold operating parameters. As an example for an optimal effectiveness of the FAST System, the Administrator is required to enter into the control mode and customize the system set up to take into account various factors of influence, including:

- The density of the traffic
- The selected sites for the installation of the meteorological and road sensors
- The local climatic variations
- The choice of the spraying parameters.

After appropriate training is given by the Vendor, and under the direction of the Owner, the Administrator is able to modify and enter parameters. The vendor advises however that they will not be held responsible for the consequences of hazardous, incomplete or lack of customization of the system.

At the lowest level, a user would be permitted to only to view current and historical pavement, atmospheric and system operating data, but could not affect the operation of the FAST system using the interface software. Software development is underway which provides these services over the Internet to authorized users using a common Web Browser.

**Monitoring**

Notwithstanding the best efforts under the FAST installation contract, the system provides the best available technology at the time but it cannot however, be assumed to replace the requirement for regular patrols and manual monitoring of pavement and forecasts of atmospheric and pavement conditions.

This system is only a decision support system and is intended to assist the road maintainer in making informed decisions about road maintenance. It provides additional information allowing for proactive approaches to winter maintenance. MTO should be continually monitoring the performance of the system to ensure that the system is operating as intended and is applying deicing chemical at the appropriate time.

The system, on its own, on a regular basis, performs a self-diagnostic test to confirm it is ready to fire. In the event that the system detects a fault, it issues an alarm at the pump house, which is relayed to the RWIS RPU and is picked up by the server and identified as an alarm on the user interface. In the event of an alarm the nature of the fault must be determined by the system operator and the situation remedied before the FAST will fire automatically again. Depending on the nature of the fault (e.g. low level or loss of pressure) may not allow the system to fire at all. The FAST has been installed and employs the default settings provided by the vendor, based on dialogue with the MTO staff. The system will fire based on its response to a number of environmental, atmospheric and pavement condition parameters and is typically running in automated mode. It is difficult to confirm pavement conditions without relying solely on the system log to the conditions. As such currently, MTO relies on the Patrol Supervisor to verify system operations. It has been suggested that video monitoring be performed so that the timing and conditions for
chemical application can be visually confirmed as well as the response of the vehicles to the conditions and deicing chemical application.

MTO retained MFPA to provide the monitoring services based on a daily review of the system operation weekdays -Monday to Friday. Operational reviews are done during and after a winter event and a monthly review and summary report is prepared for submission to MTO; The monitoring relationship is based on the following understanding of the relative responsibilities:

- The FAST system employs a number of preset but customizable routines to respond to various alarms the system will generate. The appropriate response to the alarm and therefore the routine is also dependent on the deicing chemical employed since each chemical has a different freeze point, tracking, hygroscopic properties and results in a different coefficient of friction Boschung provided the logic and timing parameters for the application of the selected anti-icing/deicing liquid chemical based on input from MTO.

- MFPA as system administrator, on behalf of MTO provided the necessary resources to monitor the system operation to ensure that the system is continuously operating in the ready mode and no system alarms have occurred during the self-diagnostics testing.

- The FAST system employs a number of internal and external subsystems and components, which operate in an extremely harsh environment. Communications, and power are provided to the remote location via overhead lines. Each of these components is essential to the operation of the system. Robustness of the entire system and the continued access of data into the road maintainer is the aim of the system administrator. The System Administrator is responsible for the electronics, but also, communications, software and hydraulic systems. Proactive regular monitoring of the all components of the system to ensure the system is continuously in the ready mode is essential. Reliability is essential to development of confidence in the system by the Roadway Maintainers. In the event of trouble the System Administrator must have available:
  - The knowledge to troubleshoot the problems remotely
    - Identify the problem and isolate the source
    - Review standard troubleshooting list
    - Refer to manufacturer
    - Identify the remedial/corrective measures
    - Undertake the corrective measures
      - Remotely
        - By System Administrator
        - By the vendor and manufacturer's representative
      - On site
        - Hardware
        - Software
  - The knowledge to troubleshoot the problems on site
    - Identify the problem
    - Review standard troubleshooting list
    - Manufacturer Support line
    - Identify the remedial/corrective measures
    - Undertake the corrective measures
Remote Service

If problems in the system are identified, then MFPA will:
- Co-ordinates service personnel and dispatched staff to affect repairs
- Identify and co-ordinate warranty service
- Recommend appropriate repair methodology
- Isolate problems or if necessary refers them to the system designer (Boschung) when required for advice and remote system repairs
- Advise the MTO of all activities through the Contract Administrator

On Site Services

If work is required at the site, then MFPA:
- Provides field supervision of all warranty and non-warranty repairs
- Undertakes repairs, if possible, at the approval of the Contract Administrator
- Under the Maintenance portion attends the site on two occasions, in the spring and fall, for site inspection and general maintenance system review i.e. filters, pumps, RWIS components and the same and affect any required maintenance.

Lessons Learned

Design and Installation

A number of lessons were learned through the process of designing an installing the FAST system at the 416/401 interchange:
- Feasibility studies are necessary to identify and address technical design and systems issues; structural and aesthetic concerns; costs and warrants for the installation of a FAST system. The rationale for installing a FAST system should be based on a benefit/cost analysis, which takes into account the accident statistics for the site.
- Study, design and project management fees are in line with other Information Technology (IT) systems integration assignments involving hardware and software deployment, but may be greater than those for traditional roadway infrastructure.
It is important that local engineering, project management, and coordination services are available throughout the design and implementation process to deal with existing local regulations, conditions, site topography, vegetation, utility services and on site installation details which cannot be provided effectively by a vendor who may be located out of province or country.

● Appropriate coordination for utilities and an allowance for lead time, and cost when extending services to a remote site, is required.

● Shipment of materials from out of the country and overseas presents some unique challenges. Materials manufactured and supplied though NAFTA are not subject to duties. Changes in the exchange rate can occur between the time budgets are prepared and when final costs are incurred.

● Vendor bill of materials and shipping documents should be carefully reviewed and confirmed prior to shipment. Components not provided by the vendor must be identified and sourced. Sufficient accommodation must be made for delivery of unique components from a time perspective.

● Complete detailed installation manuals are required from the Vendor during design;

● Wiring from European vendors must be fully inspected by the appropriate electrical inspection authority. Personnel servicing the electrical equipment must be aware and provided with adequate instruction from the vendor.

● Licences for proprietary user interface software must be flexible enough to allow for access by the full range and number of interested parties. Internet Browser enabled access using secure passwords is the preferred mode. Both dial up and WAN access must be available.

● System data server must allow for full access to atmospheric, pavement and FAST data to allow for data mining by the system administrator(s).

● The Vendor should make a full description of the FAST system decision logic, programs and default variables available to the Owner.

Operations

It was expected that adjustments in "operations" would be required as a result of implementing FAST. Operational adjustments would take place on two fronts: physical operation of the FAST system, and in business processes for the contractor and owner's winter maintenance activities.

A number of changes have been made in the system and team operations, which include the following:

● Sufficient storage reservoir for chemical must be provided on site. Originally the vendor had indicated that the reservoir tank should have sufficient chemical capacity to last most of the season, however early in the monitoring season it became apparent that his would not be the case. The system regularly reported alarms for low chemical levels in the reservoir. The maintenance contractor modified operations in that he would on a weekly basis top up the pump station reservoir on site and ensure the on site storage tank was refilled. After an intense event such as a freezing rain storm, the levels would be checked, and during the fall, despite there not having been precipitation, chemical levels may be down as a result of firings to address early morning frost.

The upper edge of super elevated bridges should be cleared of snow. During the early part of the operating season it was observed on site that the plowing operations left some residual snow and ice on the upper shoulder (east side of the structure) and that on sunny days it melted and ran across the structure. The pavement sensors detected the moisture and since the air temperature was below freezing triggered firing of the system. The snow and ice was removed on a regular basis and no further unexpected sprays were recorded. Icicles were observed on the structure during one early winter event however the phenomenon was not observed again and was therefore attributed to a unique weather phenomenon.

Early Warning for Maintenance Contractor. Part of the attraction for implementing the system from the Maintenance contractor's perspective was that the information derived from the 416/401 FAST could be extrapolated to other similar structures within a reasonable distance from the site so long as they were in a similar microclimatic region. The teams vision was that the server would be located at the MTO district office in Ottawa which is staffed twenty-four hours a day, seven days a week by ministry staff. When the system would generate an alarm of pending ice, the dispatcher could then alert other ministry staff and the contractor that other similar sites would likely require attention. In doing this, the contractor would develop a system, which would allow them to extrapolate the known conditions at the 416/401 to other sites based on their expert knowledge of the relative local conditions at other points/structures of concern. However to realize the entire benefit of the expert system, more effort is required on behalf of MTO to ensure dispatch staff are trained to read the system user interface and respond appropriately to the alarms generated from the system.

Adjustment of operating parameters versus successful reduction in accident statistics. The Monthly Report Process afforded the opportunity to review and potentially adjust vendor suggested default parameters so as to optimize the use of deicing chemical and customize it for agency or local preferences. As an example, it was found that the system did indeed deactivated one particular program in the event of a heavy snowfall, however it continued to fire using another program once it's threshold parameters had been met. The rationale for implementing the FAST system was to determine if this technology could reduce the number of weather related accidents. The installation has been a complete success effectively eliminating accidents during a severe winter season. The cost of chemical supply however was in the order of $12,000 verses an original estimate of $5000-7000. For the peace of mind, the increase is a minimal cost and in point of fact the capital cost of the entire installation may have been offset in the first year of operation when compared to the cost of the incidents from the previous year. The system vendor has only provided a limited amount of documentation on the system decision logic and rationale behind the parameter settings citing decades of experience in the field and unwillingness to disclose proprietary intellectual property. It is of questionable value to expend a significant amount of effort to reverse engineer the logic and then assess the data for what would amount to a limited relative benefit in savings of chemical.

The extent of people requesting access to the system using the vendor's proprietary user interface software has far outreached the number initially anticipated. The Vendor has only allowed a limited number of licenses, which is insufficient to address the large number of team members and staff who would like to view the relevant pavement, atmospheric and system information. The system administrator has worked with Environment Canada who is developing an interface, which will allow permitted users to the view relevant FAST system information using their internet browser.

It takes time to achieve "buy in" from both the owner's staff and the maintenance contractor. The
contractor must be motivated to embrace the technology via either the carrot or stick. Full integration into business processes will not occur the first season, but only as confidence in the system is developed. Training, suitable to address a variety of levels of expertise, will be required on an ongoing basis as a result.

- **Potassium Acetate** has proven to be an excellent deicing chemical for this limited area. Significant tracking of the chemical has been observed after the structure and the residual adheres well to the driving surface once it dries.

- Aside from daily monitoring of the system, raw atmospheric, pavement and system operational data was retrieved regularly from server and a **Monthly Summary Report** was produced which overviewed the operation of the system during the period. The purpose of the review was to analyze the data and determine if the system variables could be modified to improve the performance. The requirement for monthly reporting forced a regular introspective review of activities by the FAST operations team: the owner, the maintainer and the system administrator.

- The original intent was to have **Video Monitoring** available on site to assist in system performance appraisals aid in the assessment; however, the video monitoring was not available for the winter of 2000/2001. The system administrator as author of the monthly report therefore had to rely more heavily on data mining, data analysis, daily monitoring and field observation by the maintainer as a source of information.

- **Access to the FAST server** was required on a number of occasions during non business hours to reset modems, which were preventing access to system data by dial up clients. The system was configured to allow dial up access through either the Ministry's WAN/LAN or via dial up connection. The WAN/LAN connection which was the primary access for the Ministry was the most reliable, however, access by the contractor, system administrator/monitor and system vendor, was interrupted on a number of occasions since the modems locked as a result of phone line or power interruption. A redundant server was set up by Environment Canada to retrieve data directly from the site. The Environment Canada server provided an alternative source of data for the team members relying on dial up connections at those times.

- The vendor's user interface software proved to be **compatible only with Windows 98** for dial up, NT and 2000 for LAN and many of the Ministry's PC's were still using Windows 95 and 98 which impeded user interface installation.

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**Reduced Environmental Impacts**
Environment Canada is reviewing whether road salts are hazardous to the environment and have proposed the following with respect to an amendment to the Environmental Protection Act:

"Based on the available data, it is considered that road salts are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity and that constitute or may constitute a danger to the environment on which life depends. Therefore, it is proposed that road salts be considered "toxic" under Section 64 of the Canadian Environmental Protection Act, 1999 (CEPA 1999)."

Potassium Acetate, as the deicing chemical, is not on the proposed list.

Other relevant advantages of the use of FAST system technology include:

- Application of deicing chemicals just in time, immediately in advance of a critical event maximizes safety but reduces the amount of chemical lost from the traffic passing, and as well avoiding application of chemical when an event does not materialize.
- Minimizes the quantity of chemical applied by ensuring it is effectively applied, uniformly, as a mist and takes advantage of vehicle tracking to the greatest extent possible.
- Just in time application of deicing chemical in advance of a critical event in an anti-icing application has proven to be effective in breaking the pavement to ice bond and substantially reduces the effort (labour and material) required for snow and ice removal.
- Potassium Acetate does not attack steel and concrete and hence the use of FAST may extend structure life and potentially reduce future rehabilitation costs. Tracking of salt from the previous section of highway is a concern so the Fast system also covers the approach to the structure.

**Conclusions**

- The lessons learned from the previous section may be of interest to other road authorities considering a similar system.
- The Ministry is very pleased with the FAST installation in terms of its success since weather related accidents have not occurred since it has been in operation.
- MTO will in the upcoming year require the contractor to interrupt application of deicing salts across the structure now that the results respecting the safety of the structure have been achieved and functioning of the FAST system has been confirmed.
- The Ministry currently reviewing additional applications at locations where it appears FAST may be warranted.

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