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Wireless Sensor Monitoring of Heat Distribution Systems for Corrosion Prevention

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ABSTRACT

This Office of Secretary of Defense Corrosion Prevention and Control project demonstrated the application of robust sensors for heat distribution manholes. This project implemented robust (i.e., able to withstand the combination of extreme heat and humidity) sensors in manholes at Redstone Arsenal, AL, which provided real time manhole condition/status information. For each manhole, redundant sensors were used to monitor ambient temperature and water level, if any. The detected presence of any water gave an indication of potential problems such as a sump pump failure in the pit. Water detected near the lowest height of the distribution piping would indicate a critical situation in need of immediate attention. Two wireless communication technologies were used for the sensors to demonstrate different potential capabilities of communication for the sensors. Conventional cellular technology was used for eight of the manholes monitored. The cellular Remote Transmitting Unit (RTU) was programmed to send an email alert whenever water was detected in the pit, or when the temperature exceeded a pre-determined threshold. In eight other manholes, RTUs were installed that were capable of integrating into the installation's existing Supervisory Control and Data Acquisition (SCADA) network. Following the demonstration with the selection of materials and monitoring equipment, it is estimated that each monitoring system could potentially this could yield a net present value of the savings of more than $534,000 over a 30 year lifespan.

Key words: wireless sensors, leak detection, ambient environment monitoring, corrosion prevention

INTRODUCTION

Heat distribution systems (HDS) are used throughout the Army and Department of Defense (DoD). They represent both a significant initial expense (typically between $750 to $1,000 per foot for piping as well as an ongoing operational expense to produce the steam or hot water and supply it to buildings on the installation. When functioning properly these systems are reliable, cost effective and allow for the

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adaptive contingency of fuel switching at the central boiler plant. However, there is also the potential to lose large amounts of excess wasted heat during distribution while accelerating the corrosive degradation of HDS components in the process. Manholes were long ago identified as a source of premature failure in buried heat distribution systems[1]. This typically occurs in below grade system manholes that become unable to collect and remove via sump pump any accumulated ground water and/or leaking carrier fluid. Flooded manholes are at a near optimal temperature to nucleate boiling, and the U.S. Army Corps of Engineers has estimated that excess heat loss ranges from $50,000 to $125,000 per year if not repaired.[2]

This work in this paper sought to design and install robust sensors for both temperature and humidity in HDS manholes at an Army installation. Similar efforts have been being undertaken by a utility service company for steam distribution systems in New York, NY[3]. The demonstration site for this project was Redstone Arsenal, AL where the HDS uses 180 PSIG (1.24 MPa) steam (380 °F / 193 °C saturated). The term robust indicates that both types of sensors must be capable to withstand extremes of both temperature (up to 300°F / 149°C) and humidity (up to 100%), which is typical of HDS manholes, especially in a damaged or failed state of repair. Communication of real-time (or within two hours) data measured by the sensors was transmitted via a wireless technology and communicated to a central location. Figure 1 is an image of a typical HDS manhole and diagram of the sensor configuration installed. For each manhole multiple sensors were used to monitor ambient temperature and water level, if any. The detected presence of water gives an indication of possible problems (with sump pumps or otherwise) while water detected near the lowest height of the distribution piping flags a critical situation in need of immediate attention. Ambient temperature readings were also taken for both confirmatory purposes and to alert to the sudden release of pressurized carrier fluid (i.e., blown steam trap, catastrophic valve packing leak, etc.).

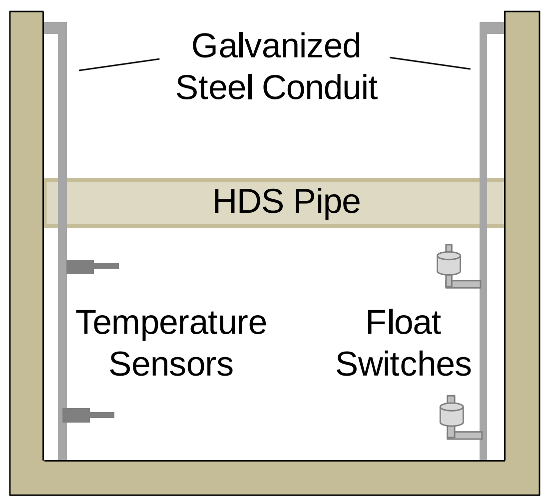

Figure 1: Typical manhole (image) and sensor layout (schematic).

EXPERIMENTAL PROCEDURE

Two wireless communication technologies were used. First, eight manholes were monitored using conventional cellular, or Global System for Mobile Communications (GSM) technologies. The cellular RTU was programmed to send an email alert whenever water was detected in the pit, or when the temperature exceeded a pre-determined threshold. In addition, RTUs capable of integrating into the installation's existing SCADA network were installed at eight other manholes. Redstone Arsenal's

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SCADA network operates on a 900-MHz line-of-sight Ethernet network, with a central antenna located onsite.

The temperature was monitored using Series 68[(1)] Resistive Temperature Detectors (RTD) temperature sensors, as shown in Figure 2a. These sensors are rated for operation between -58°F and 752°F (-50°C - 400°C). Float switches monitored water levels in the manholes. The FS11-001,[(2)] shown in Figure 2b, were constructed from 316 stainless steel to aid in temperature and corrosion resistance. The switch had 1/8 in (3.175 mm) pipe threads for mounting, using 22 gauge copper wires with Polytetrafluoroethylene (PTFE) coating for resistance to elevated temperatures. One switch was installed at the bottom of each pit no farther than 6 in (15.25 cm) from the bottom of the manhole. This switch was intended to provide an initial warning when water begins accumulating in the manhole. A second switch was installed 24 in (61 cm) from the bottom of the manholes. This is intended to provide a final warning before pipes or valves begin to be submerged.

The RTU used for the SCADA-monitored manholes, SEL-2411,[(3)] was chosen because it has sufficient digital inputs to read the float switches, and is capable of interfacing directly with the RTD temperature sensors. For the cellular monitoring, the T-BOX Lite[(4)] was chosen because of the integrated GSM modem. With this modem, the RTU was configured to send emails or text messages directly to the party responsible for monitoring, without need for a central monitoring station (as in a SCADA system). All of the RTUs were mounted in weatherproof NEMA-rated enclosures, as shown in Figure 2d.

The RTUs for the GSM-monitored manholes were programmed to send alarm emails to a pre-defined address when an alarm condition was triggered. Alarms were set when either level switch was closed, and when either temperature sensor read a temperature above 180°F (82°C). When alarms were triggered, they sent notifications to the Redstone public works representative and the relevant operations contractors. In addition, each RTU was programmed to log temperature measurements hourly, and to email this to appropriate personnel at midnight local time. These daily emails served as verification that the system was functioning properly.

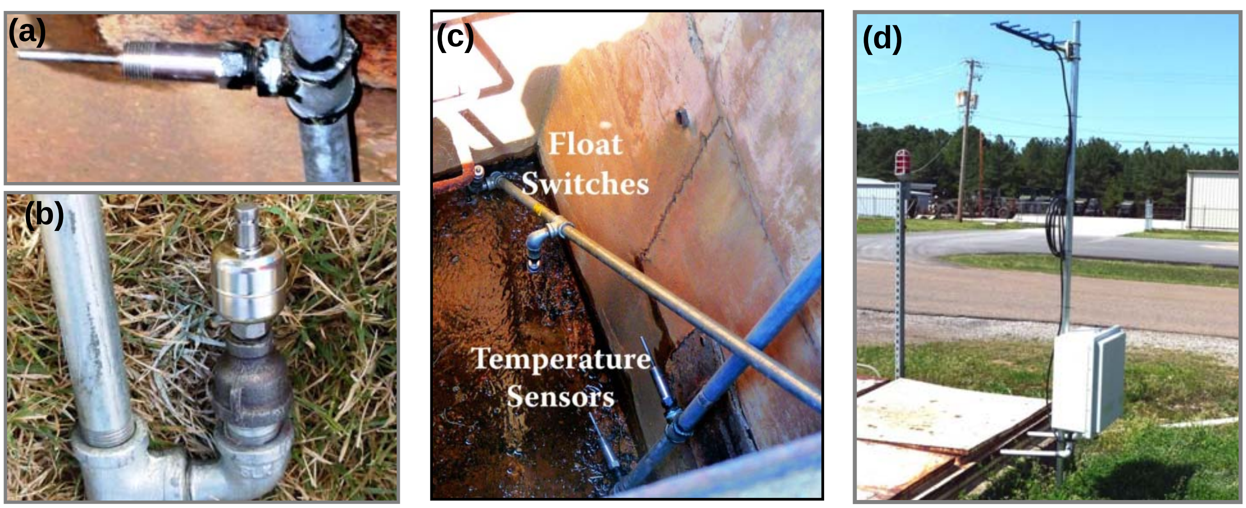

Figure 2: (a) Temperature sensor, (b) float switch, (c) installed temperature and water sensors, (d) weatherproof enclosure and antenna for a SCADA-monitored manhole.

(1) Trade name from Emerson Rosemount Measurement Division
(2) Trade name from SMD Fluid Controls
(3) Trade name from Schweitzer Engineering Laboratories
(4) Trade name from CSE Semaphore Inc.

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RESULTS

The cellular RTUs (and attached sensors) performed as designed and expected. Temperatures were reported daily for all manholes that were supplied with electrical power. While the main purpose of this effort was to provide daily verification that the system was still functioning properly, it also created a record of internal pit temperatures at the manholes where the cellular system was functioning. The data from cellular manholes were difficult to process as they are contained in daily emails. Sample data from T-Box 2 has been processed and is shown in Figure 3, indicating periods where the ambient temperature increased, but no significant issues with the manholes were observed during the demonstration.

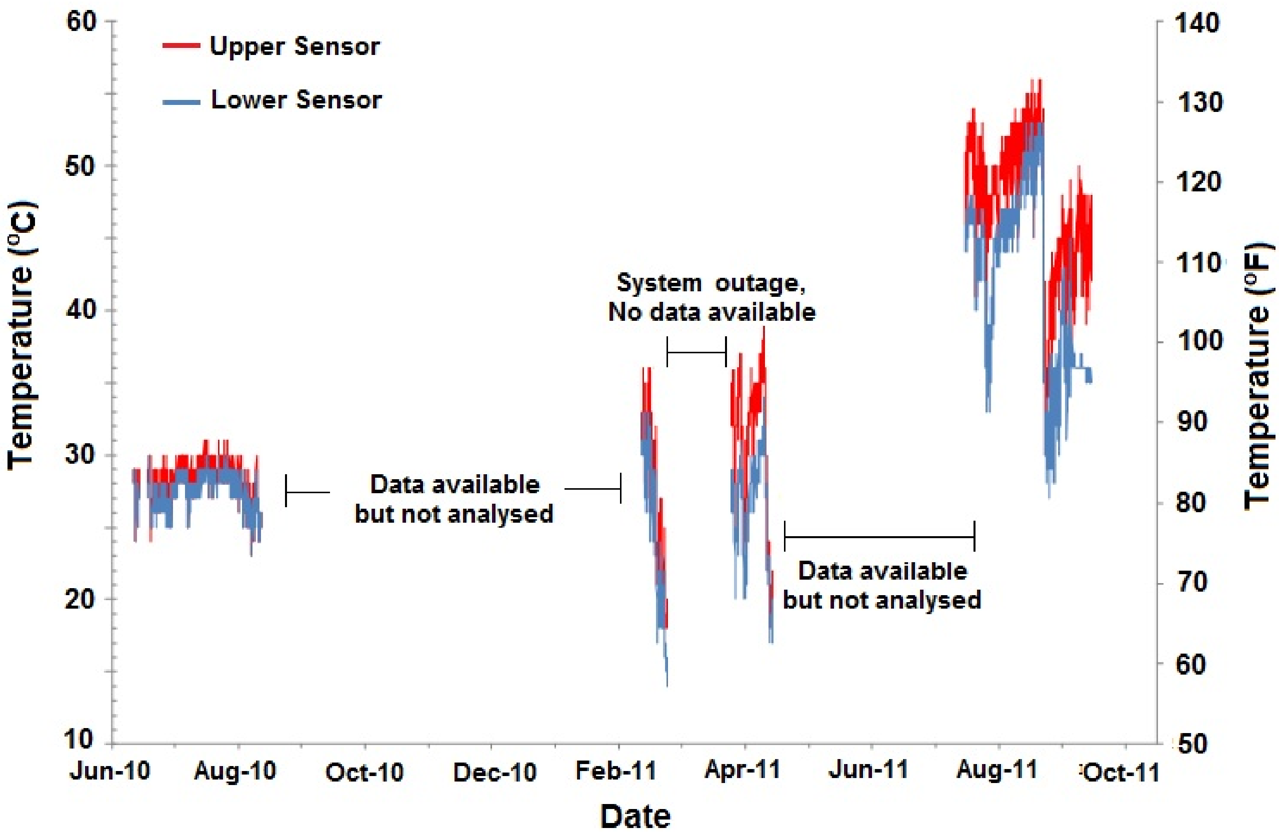

Figure 3: Sample data from one of the seven cellular manholes.

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Level alarms triggered periodically, as shown in Table 1, usually during periods of sustained heavy rain at Redstone Arsenal. It is theorized that the heavy rain caused the level of the groundwater to rise, accelerating the leakage into the pit, and temporarily exceeding the capacity of the sump pumps to remove water from the manholes.

Table 1: Level Switch Activity.

Pit Location	Lower Switch	Date/Time	Upper Switch	Date/Time
Pit C2	X	9/18/11 0756		
Pit C7			X	10/10/10 2245
			X	10/10/10 2248
	X	10/24/10 2209	X	10/24/10 2236
	X	11/29/10 2315	X	11/29/10 2326
	X	12/31/11 2235	X	12/31/11 2241
	X	1/1/11 0336		
	X	1/3/11 2034		
	X	1/3/11 2051	X	1/3/11 2106
	X	1/3/11 2154	X	1/3/11 2209

From an economic perspective, the use of monitoring represents a modest cost in comparison to the value of the entire heat distribution system. Table 2 details the costs of the cellular and SCADA systems. The total installed cost of the cellular system was $5,648.12 per pit. This included $72 for the first year's cellular subscription with the $6 per month cellular subscription cost will recur for the life of the monitoring system. The total installed cost of the SCADA system is calculated to be $6,285.70 per pit. For the SCADA pit, the incremental cost of monitoring an additional node on an existing SCADA network was assumed to be zero.

The manholes would typically boil for an average of a month undetected without the system, and can experience a monthly cost greater than $4,300 for loss of heating energy. With the evaluated monitoring systems in place and a more active repair of manholes experiencing boiling or active steam leaks would be damage prevention to the adjacent portions of the HDS when a manhole floods. Assuming the aforementioned capital and maintenance costs of the cellular or SCADA systems, plus a cost of $750/foot ($2,467/m) and 350 feet of pipe needing to be replaced every five years, this could yield a net present value of the savings of more than $534,000 over a 30 year lifespan.

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Table 2: Capital costs for monitoring systems.

Cellular System

Item	**Cost**	**Quantity**	**Extended Cost**
TBOX Lite	$1,882.50	1	$1,882.50
GSM Antenna	$95.00	1	$95.00
Antenna Cable	$35.35	1	$35.35
Lightning Arrestor	$240.00	1	$240.00
Power Supply	$58.50	1	$58.50
Cable (T-Box - Lightning Arrestor)	$31.50	1	$31.50
Terminals, wires, etc	$100.00	1	$100.00
Cell Activation, SIM Card	$39.95	1	$39.95
Monthly Cell	$6.00	12	$72.00
Temp Transmitter	$260.47	2	$520.94
RTD Temp Sensor	$193.55	2	$387.10
Enclosure	$82.48	1	$82.48
Level Switches	$33.60	2	$67.20
Sensor mounting, conduit, attachment, etc	$200.00	1	$200.00
Installation labor	$1,835.60	1	$1,835.60
Total (per pit)			**$5,648.12**

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SCADA System

SEL-2411	$1,374.00	1	$1,374.00
Enclosure	$395.00	1	$395.00
FreeWave Radio	$1,650.00	1	$1,650.00
Coax Jumper (from radio to lightning arrestor)	$30.00	1	$30.00
Lightning Arrestor	$55.00	1	$55.00
Cold Shrink Kit	$22.00	1	$22.00
Yagi Antenna	$140.00	1	$140.00
DIN mounting kit for radio	$35.00	1	$35.00
Antenna Cable	$95.00	1	$95.00
RTD sensor	$193.55	2	$387.10
Level Switch	$33.50	2	$67.00
Sensor mounting, conduit, attachment, etc	$200.00	1	$200.00
Installation labor	$1,835.60	1	$1,835.60
Total (per pit)			**$6,285.70**

CONCLUSIONS

This project has demonstrated the ability to remotely monitor the operating conditions in heat distribution system manholes. Both temperatures and water level monitoring was demonstrated. In addition, two methods of relaying the data from the manholes to a central point where appropriate actions could be taken were demonstrated: use of the base-wide SCADA system, and the now-pervasive use of cellular telephone technology. Although potential savings of using a monitoring system can only be estimated, roughly $534,000 over a 30 year timeframe, the benefits tremendously outweigh the modest equipment costs. The technology demonstrated would be applicable on any military or civilian facility (i.e. hospital complexes, college campuses, etc.) that uses a heat distribution system with manholes. There may also be applicability to other types of manholes such as those found on chilled water, electrical, and communications systems that are buried.

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