

Internal Corrosion Detection in Liquids Pipelines

Final Technical Report

Contract DTPH56-08-T-000020
Pipeline & Hazardous Materials Safety Administration

Prepared for

US Department of Transportation
Pipeline & Hazardous Materials Safety Administration
1200 New Jersey Avenue, SE, E22-229
Washington, D.C. 20590-0001

Prepared by

Ashok Sabata, Ph.D.
Aginova Inc.
3 Chambry Ct
Freehold, NJ 07728

January 2012

TABLE OF CONTENTS

TABLE OF CONTENTS	ii
1 INTRODUCTION	3
2 OBJECTIVES	3
3 DEVELOPMENT WORK IN PHASE II	4
3.1 Acoustic System for Location.....	4
3.1.1 Development of Sensor Electronics.....	5
3.1.2 Software – Drivers and Firmware.....	6
3.1.3 Software and Electronics Testing	8
3.2 Objective – Location Determination.....	8
4 SUMMARY AND WAY FORWARD.....	11
4.1 Summary	11
4.1.1 Hardware Prototype	11
4.1.2 Testing in a test loop	12
4.2 Way Forward	12

1 INTRODUCTION

PHMSA project DTRS56-05-T-0005 "Development of ICDA for Liquid Petroleum Pipelines" led to the development of a Direct Assessment (DA) protocol to prioritize locations of possible internal corrosion. The underlying basis LP-ICDA is simple; corrosion in liquid petroleum systems is most likely where water and/or solids accumulate. Despite the development of this protocol, it still suffers from the same limitations as other DA methods in that no direct measurement regarding the pipe or the environmental aggressiveness is made. That is, the LP-ICDA methodology attempts to predict the locations most likely to experience internal corrosion in liquids lines but then the operator needs to conduct subsequent evaluations, such as ILI runs or excavations both of which are expensive and may not always be easy to accomplish, to confirm the LP-ICDA predictions. The method developed here is a complimentary technology that can be used in both piggable and un-piggable pipelines that is capable of making direct measurements of the corrosive environment that may be present at the locations predicted by LP-ICDA.

The goal of the project team was to build a prototype and test in the lab and for validation in field. Based on the outcome of the lab tests and field trials, additional modifications and improvements were envisioned to better enable the acceptance and adoption of this technology by pipeline operators and regulatory agencies. To accomplish this objective, the following tasks are proposed:

1. Assemble a prototype that can detect water as well as provide its location
2. Conduct trials in the laboratory to validate its operation in pipeline conditions
3. Conduct trials in the field and identify any necessary system improvements.

2 OBJECTIVES

Detecting the presence and location of water is an important component of internal corrosion direct assessment of liquid petroleum pipelines. The currently available inspection techniques are limited because some cannot be applied to all pipelines and others require prior knowledge of where to locate the sensors and require costly pipeline excavation to emplace the sensors. Recently a mobile corrosion sensor technology integrated to a wireless network platform, called motes, has been developed and tested. This proposal seeks to build upon previous efforts that have led to the development and testing of functional prototype sensor systems for gas pipelines by modifying the

Major Tasks	Challenges & Solutions
• Assemble a prototype	Measuring location in liquid We will use acoustic waves for location sensing Assemble inside 1.5" ball We will have to stack the electronics to fit inside
• Conduct trials in the laboratory to validate its operation in pipeline conditions	Prototype development is time consuming and costly The primary design components are known and off-the-shelf. Team has prior experience
• Conduct trials in the field and identify any necessary system improvements	Sensors give false negative indications Multiple sensing elements will be used on each sensor and multiple sensors will be used simultaneously

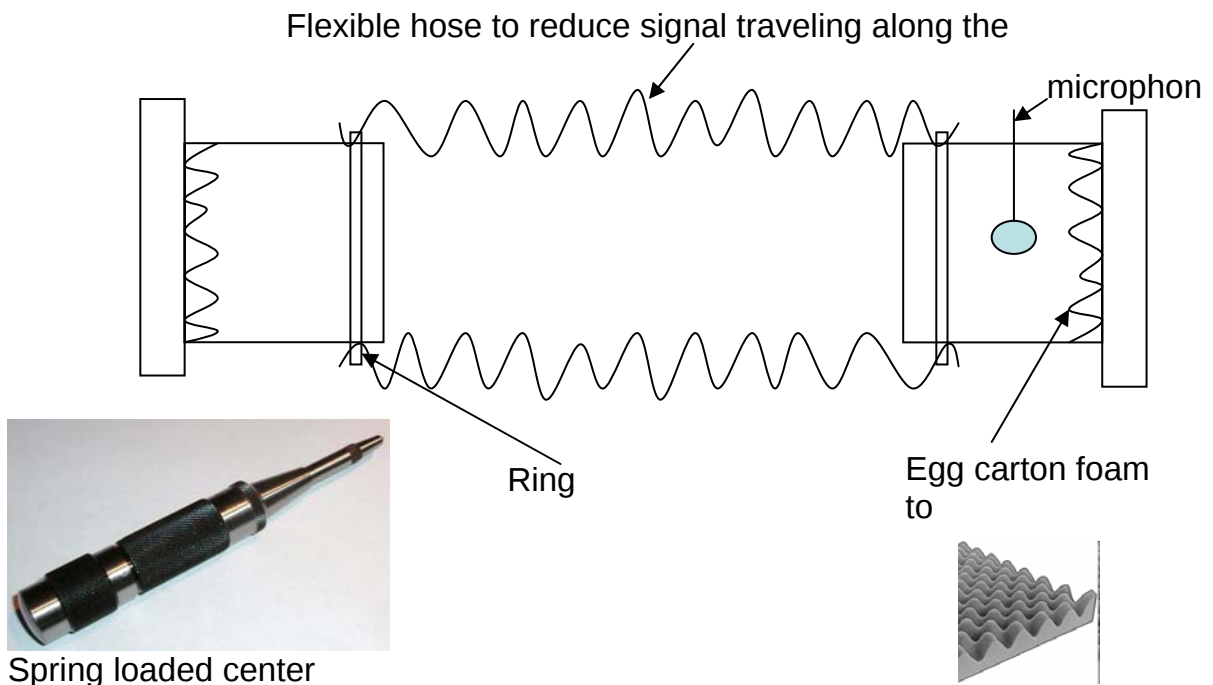
product for use in liquid petroleum lines. The challenge here is to use a unique acoustics based system for location sensing and data transmission. By developing a prototype for testing in the field will get industry and regulator acceptance of this methodology for assessing the risk of internal corrosion will be enhanced and possible improvements to the eventual commercialized system will be possible.

3 DEVELOPMENT WORK IN PHASE II

3.1 Acoustic System for Location

Since electromagnetic waves rapidly attenuate in liquids we therefore plan to use acoustic waves to estimate the location of the corrosion sensor node. Therefore an acoustic transducer is used for under liquid communication between sensor nodes and the point of sensor introduction. The sensor nodes will just have a receiver that will listen for pings and record them with the timestamp and the corresponding corrosion reading. The pings will be generated at the point of introduction of the sphere. The time of arrival of the ping at the sphere will be used to calculate the location. The figure below shows the schematic the lab fixture built to measure acoustic waves:

Measure an acoustic signal to determine distance



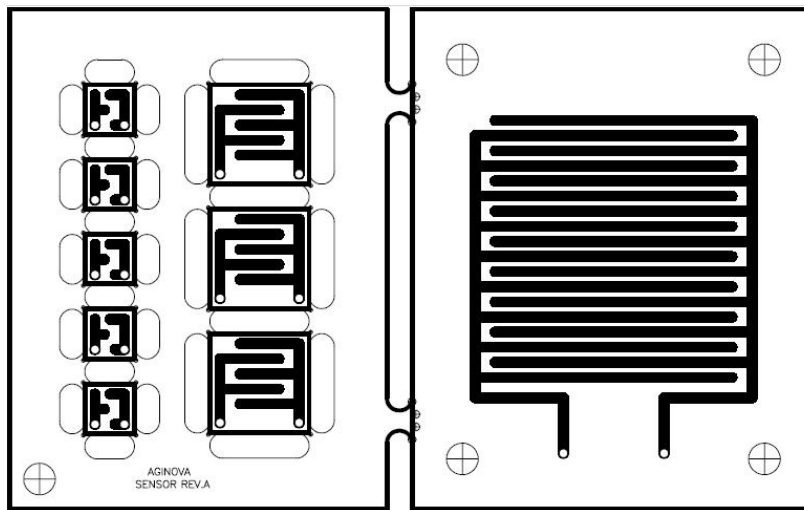
The goal was to develop electronics to measure the acoustic signal. Power to the system is supplied via 3.6V AA Li battery as the purpose here is remote application. The sensor electronics should be configured to the probe design. There was also a preference for a small footprint. Finally, a low power wireless communication system was desired for communications between the measurement electronics and an external unit such as a PDA or a PC.

3.1.1 Development of Sensor Electronics

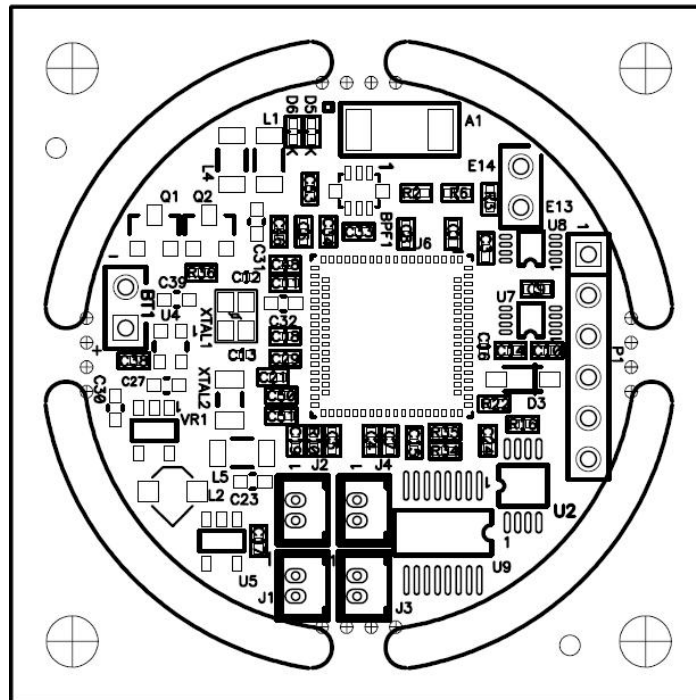
The sensor electronics was developed extensive after testing in the various components in the lab with the goal of developing electronics that would provide the lowest current at a reasonable cost. The electronics has the following distinct pieces:

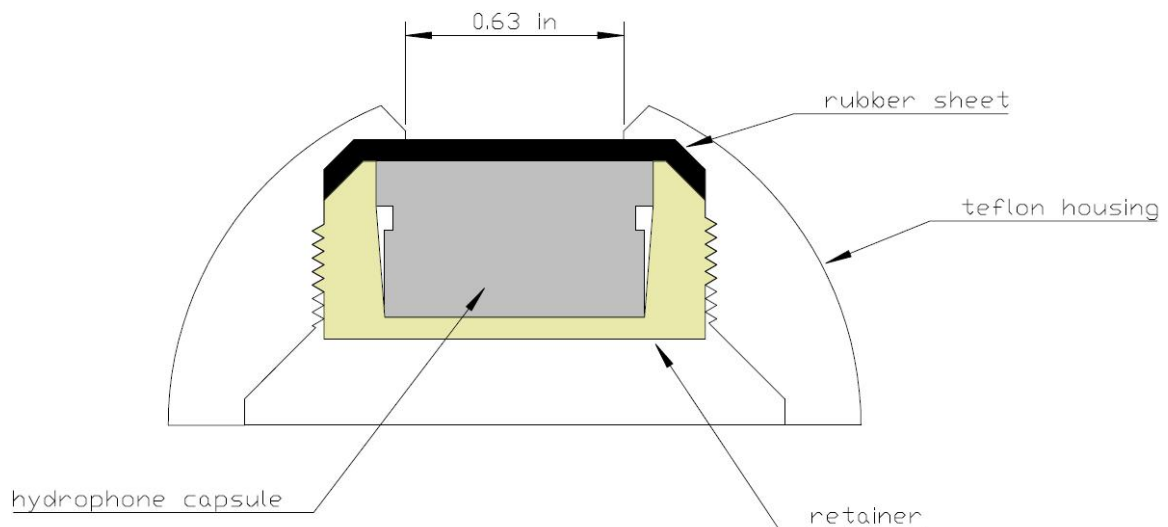
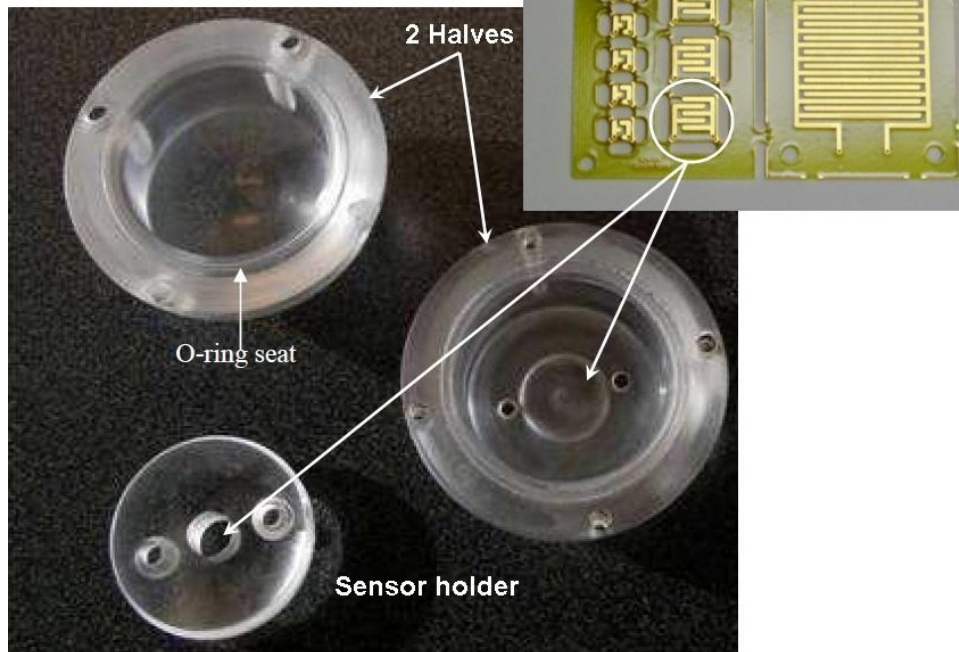
1. Sensor electronics
2. Sensor I/O (connectors to sensor)
3. Data Storage
4. Wireless Module

The Figure below is the design of the sensor head:



Electronics to control the water detection sensor:



Ball held together mechanically**3.1.2 Software – Drivers and Firmware**

The Wireless Module is an ultra low power system on a chip that combines two ARM-7 based processors with an RF transceiver, Flash memory and SRAM on a single chip. It provides a flexible platform for wireless sensors to connect to Wi-Fi networks.

The Wireless Module architecture is presented in the figure below.

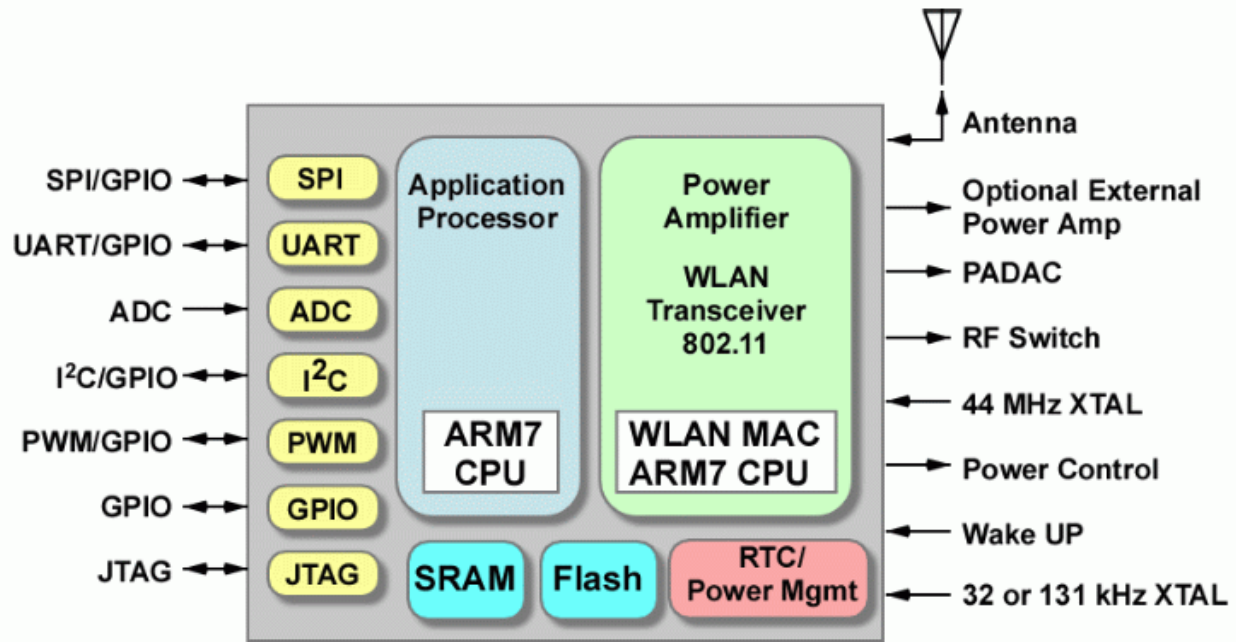


Figure: Wireless Module architecture

The Wireless Module embedded software is organized in the following way: one processor executes firmware that manages the radio and WLAN interface; it is called the WLAN CPU. The second processor – the APP CPU - executes application firmware.

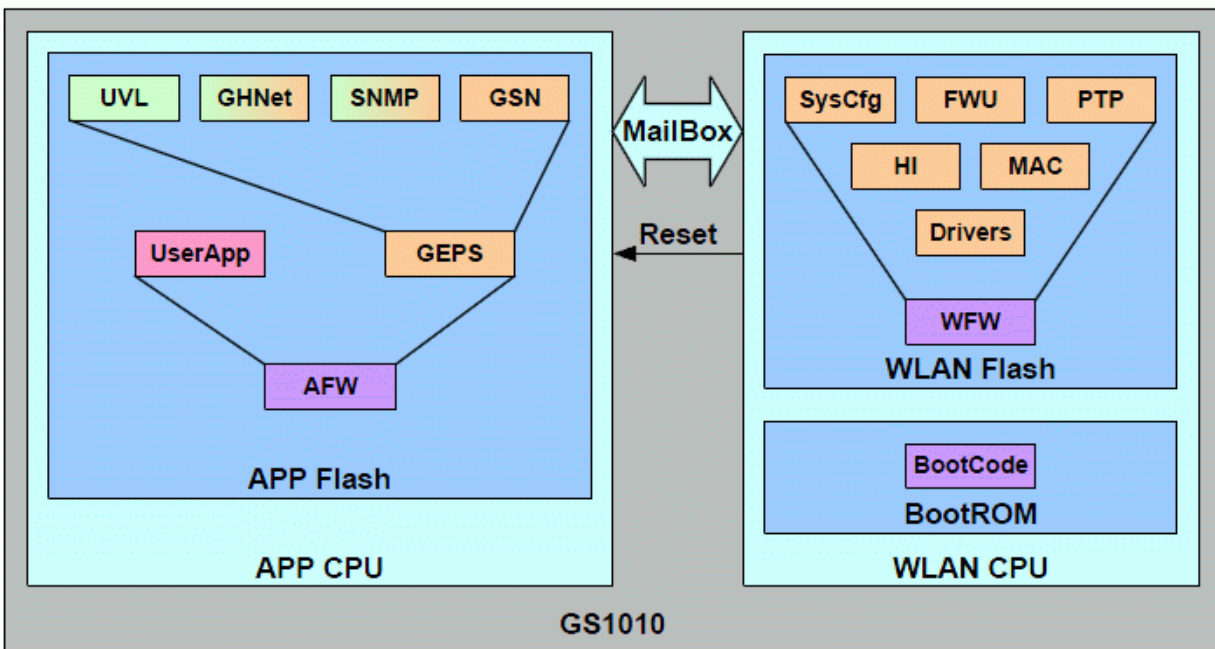


Figure: Embedded Software Overview

The application software is composed of the User Application (UserApp) and the Embedded Platform Software (GEPS). The UserApp is the main component that the Application Programmer uses for defining the product.

The UserApp mainly contains the following:

- Drivers for communicating with other parts (through SPI, I2C, etc.)
- Communication-specific code (heartbeats, etc.)
- Storage-specific code (buffering, store and forward, etc.)
- Product-specific code (sensor readings, measurement algorithms, etc.)

3.1.3 Software and Electronics Testing

Once the firmware is written, the wetness board sensor electronics can be evaluated. In order to do this, a Druck UPS-III Loop Calibrator is used with a voltage divider, a combination that allows to source currents in the -10uA to +10uA range. This current source is connected between channels 1 and 2 of the wetness board and the ADC code is reported for the full range of currents.

The ADC Output Code can then be converted to current using the following formula.

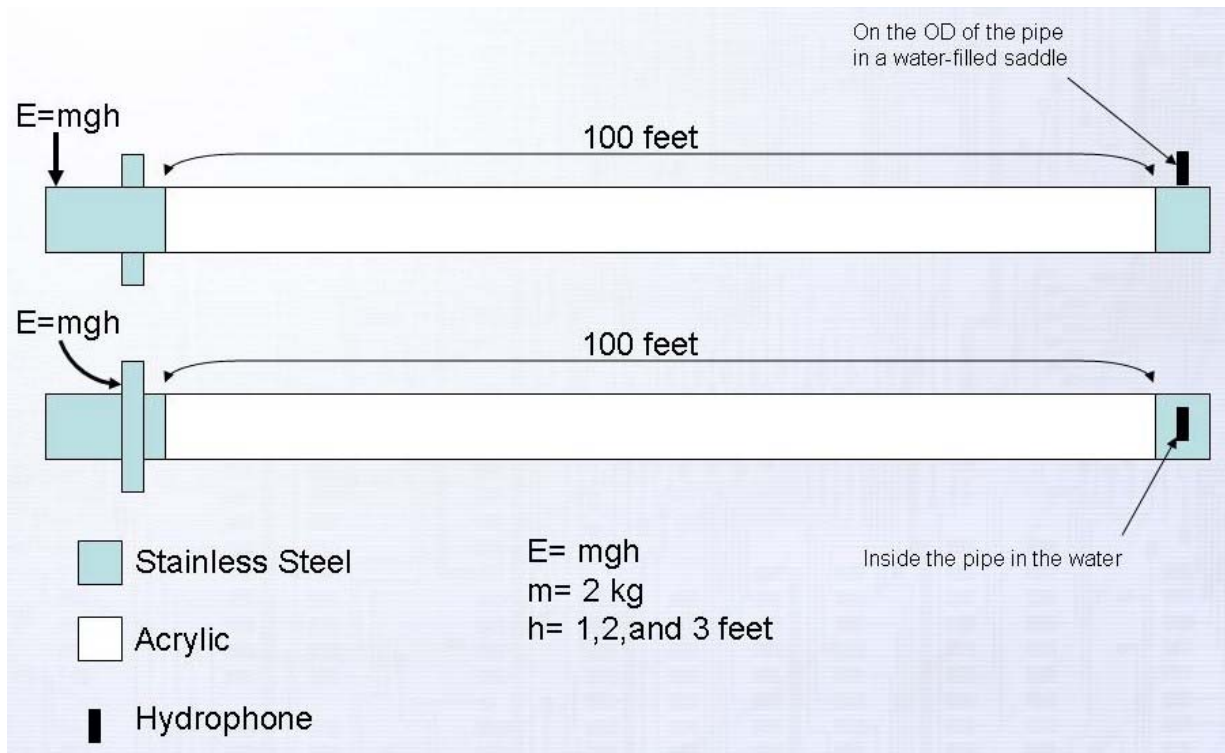
$$I = \text{ADC_output_code} / 1.29892e9$$

3.2 Objective – Location Determination

The Table below summarizes the setups built for the various acoustic experiments

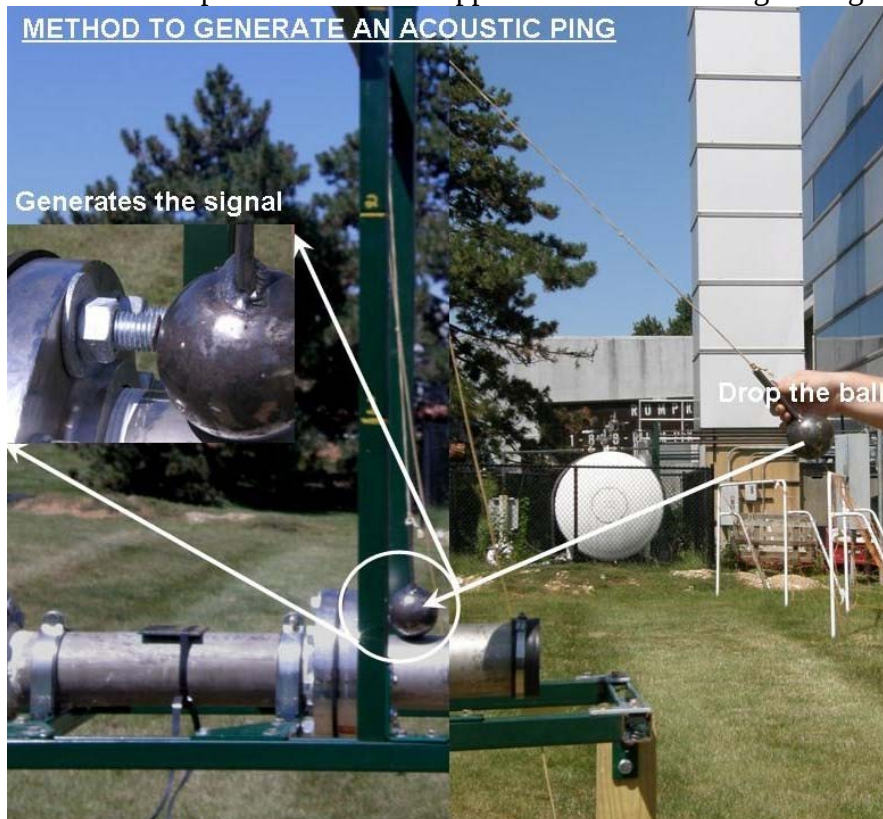
Type of Setup	Length	Acoustic Sign Generator	Method for Listening	Key Finding
Bench top setup	6ft	Center Punch, Drop Weight	Hydrophone, Accelerometer	Able to generate/listen to acoustic signal with hydrophone Not very successful with accelerometer Saddle with hydrophone was built to be used outside pipe
Outdoor setup	100ft	Center Punch, Drop Weight	Hydrophone, Accelerometer	Center punch does not work Hydrophone inside the pipe or with saddle the best approach
Proxy field testing	~750ft	Drop Weight	Hydrophone with Saddle	Acoustic signal between 100Hz to 500Hz can be detected Trial was considered successful

Outdoor 100ft Pipeline



The ball in the picture below is dropped from different heights to generate a Ping

METHOD TO GENERATE AN ACOUSTIC PING



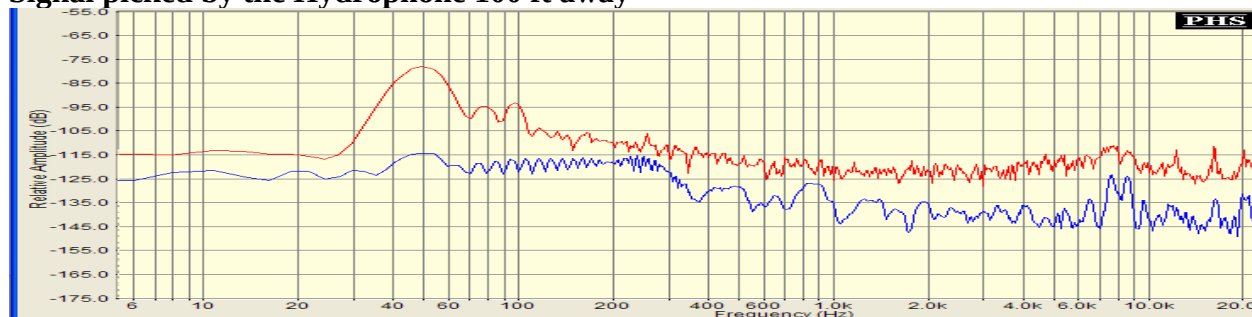
Listening to the Ping from outside the pipe



100ft Pipeline setup at DNV outdoors

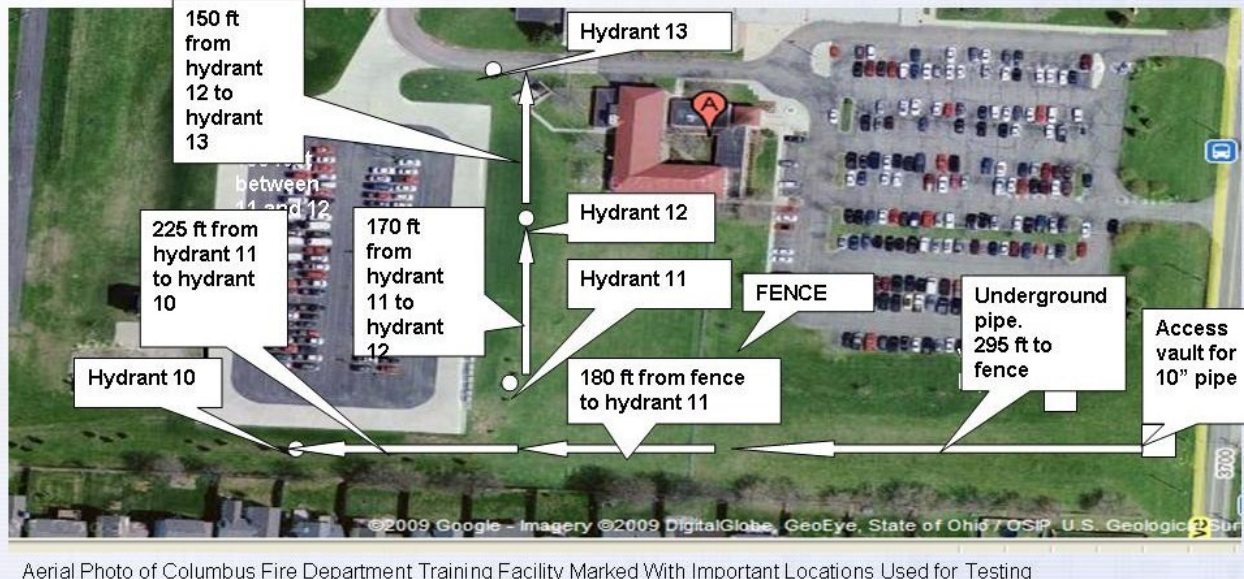


Signal picked by the Hydrophone 100 ft away



Field Trial 750ft Water Pipeline

October 1st 2009 Acoustic Field Test At Columbus Fire Department Training Facility 3639 Parsons Avenue Columbus, OH



We were not allowed to place the hydrophone inside the pipe. Therefore, we used the hydrophone with the saddle to listen to the pings from the outside.

Summary & Conclusions from the Experiments

1. We were successful in consistently generating an acoustic signal
2. The signal easily carried for at least 750 ft even when using a microphone outside
3. The frequency of interest is between 100Hz to 500Hz
4. A 2" package with the wetness sensor has been shown to be functional

4 SUMMARY AND WAY FORWARD

4.1 Summary

The following goals were proposed in the Phase II:

1. Develop a prototype hardware system for detecting water in oil pipelines
2. Develop a prototype to determine location using acoustic waves
3. Demonstrate system at a test loop

4.1.1 Hardware Prototype

We developed the hardware for moisture detection and also designed the hardware for measuring acoustic waves

4.1.2 Testing in a test loop

BP the partner for co-funding and to make arrangement for flow loop testing pulled out of the project. The project was therefore put on hold.

4.2 Way Forward

Aginova needs a partner for piloting at a test facility and then take it to the field.