

May 2014

# Copper Pipe Leak Detection

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Project Number: MQP HGV - 2000

## **Copper Pipe Leak Detection**

*Investigated in coordination with Ayotte Plumbing*

A Major Qualifying Project Report

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

In Management Engineering, Mechanical and Biomedical Engineering Concentration

by

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Date: 7<sup>th</sup> April 2014

Approved:

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Professor Helen G. Vassallo, MQP Advisor

## Acknowledgements

We would like to acknowledge and extend our sincere gratitude to the following persons who have made the completion of this Major Qualifying Project possible:

- Our advisor, Professor Helen Vassallo, for her guidance and leadership,
- Dean Ayotte and Ayotte Plumbing for their sponsorship throughout the project, aid with pipe failure related questions, and for conducting a product test trial for the Copper Pipe Leak Detection technology,
- Lynne Riley and the Worcester Polytechnic Institute Library Staff for their help and insight in our research,
- The Olympus Corporation and our Olympus contact, Paul Mespelli, for his insight and aid in finding the proper product, and for allowing Ayotte Plumbing to conduct a test trial with Olympus's innovative ultrasound technology,
- Colleen Kilfoil, Owner of ACapeHouse.com Real Estate, for providing valuable information about the applicability of this project
- The various researchers, developers, and companies who have created many of the pipe corrosion detection technologies referred to in this paper
- And, most of all, our parents whom allowed us the opportunity to study at the school of our dreams.

Without those listed above, this report would not have been possible.

## **Executive Summary**

Every year water damage from leaks in water supply systems cost property owners thousands of dollars. This damage is one of the most expensive costs amongst residential homes in the United States. Insurance companies pay more than \$3 billion a year for flood-related damages in household. These water leaks can occur at any given time and it is difficult to detect by just viewing the exterior of the piping.

Our project team was sponsored by Ayotte Plumbing, Heating, and Air Conditioning. Dean Ayotte, the president of Ayotte Plumbing, asked the team to find a non-invasive tool that helps detect leaks in water supply systems before the leaks occur and prevent damage to a property.

Ayotte Plumbing is a family own business operates throughout Southern New Hampshire and Northern Massachusetts since 1970. The ultimate goal of Ayotte Plumbing is to offer a Pipe Corrosion Inspection Service by using a non-invasive tool to detect areas of piping at risk for leaks.

A technology that allows for non-invasive leaks detection is Ultrasonic testing. Ultrasonic technology helps examine materials through high frequency sound waves. These waves are used to detect and evaluate flaws, measure dimensions, and characterize materials. Ultrasonic testing works best in discontinuous detection of surface and subsurface measurements. The depth of penetration for flaw detection and measurement is superior to other nondestructive testing methods. Reflector positioning and estimation of the size and shape of flaws is more accurate when done with Ultrasonic testing. When one is performing nondestructive testing, only a single side of access is needed to get a reading. The technology of Ultrasonic testing allows for compact and easy to use equipment.

After careful research, our project team picked the 45 MG Thickness Gauge as the Pipe Corrosion Inspection Service. The 45 MG is manufacturing by Olympus NDT, located in Waltham, MA. In the end, Ayotte Plumbing did not choose to purchase the 45 MG Thickness Gauge but will continue to look for opportunities with this device before reconsidering purchasing the product.

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## **1. Introduction and Problem Statement**

Water damage that occurs from faulty plumbing represents the most expensive damage cost amongst residential homes in the United States. Property owners can spend thousands of dollars in tear out and replacement costs, raised insurance rates, lost business/mortgage financing, and other expenses related to water damage. This kind of damage often results from leaks in failing copper pipes due to the corrosive nature of running water and natural wear and tear. Most of these damages stem from accidental release of water from pressurized sources.<sup>1</sup>

Nationwide, insurance companies pay more than \$3 billion a year for flood-related damages. The top five areas of residential water damage, according to the *Insurance Institute for Business Home and Safety* are Plumbing Supply System Failure, Toilet Failure, Water Heater Failure, Plumbing Drain System Failure, and Washing Machine Failure.<sup>1</sup>

There are multiple reasons why water damage causes expensive repair costs. Many homes and residences don't have the financial resources to afford flood protection systems. Additionally, the flood protection systems that do exist for residences and small business are usually expensive and flawed. Some systems use an alarm that warns owners about leaks by triggering an automated warning bell. These alarms are useless if nobody is on site to hear them. Individual devices that offer water shut-off features do not provide comprehensive coverage. Average flood protection systems cannot prevent leaks, but top of the line systems can autonomously shut off water at the main line roughly ten seconds after a leak or flood state is detected. These premium systems use state of the art sensor technologies, and save thousands of dollars in water and mold damage when they are triggered. Although this may prevent thousands of dollars in water damage, this type of flood protection system is very expensive after

inspection, installation, and maintenance costs. The net result is that many home and business owners do not have enough money to afford the most effective systems.<sup>1</sup>

Water leaks can happen at any time. Sometimes there is no indication of damage being done, which can lead to extensive complications that result in repair expenses. Inspections for installed plumbing systems is presently done invasively. The term 'invasively' implies that the system is temporarily shut off, excavation is done, and sections of piping are removed. Efficient inspection for internal damage of piping is a challenging task and becomes even more difficult if the pipes are coated with insulating materials. Obviously, there is a need for an affordable, reliable, and *non-invasive* pipe inspection technology.<sup>2</sup>

Plumbers have always addressed problems after the issue has presented itself. Non-invasive technology could detect leaks before they happen in an effort to prevent the extensive costs from water damage. Plumbers should apply this technology to add a preventative service, and consequentially a new revenue stream, to their business services.

The goal of this project was to find and utilize a non-invasive and affordable product that would detect leaks before they occur. Implementation of this product would add value to our sponsor's business by saving new and existing customers from the bad experience of water damage. The implementation objective of the project was to incorporate a device as a Pipe Corrosion Inspection Service provided by Ayotte Plumbing, Heating, and Air Conditioning. The objective of this report was to provide information, analyze results, and discuss related topics to give the reader a full understanding of the project.



## **2. Materials and Methods**

The materials researched were nondestructive testing equipment, piping materials and methods, and the plumbing industry in Northern Massachusetts and Southern New Hampshire. To research these topics, the project team used literature and internet research, along with professional interactions, in an attempt to implement a Pipe Corrosion Inspection Service for the project sponsor.

## **3. Results**

The result of this project was research into the viability of a Pipe Corrosion Inspection Service. Ayotte Plumbing tested the 45 MG Thickness Gauge from Olympus NDT to determine if the device could help forewarn homeowners about compromised piping. Ayotte Plumbing determined that the Thickness Gauge could not perform accurately and would result in financial losses for the company. Additionally, customers were skeptical of the technology, and this did not encourage the project sponsor to purchase the device. In lieu of completing the main objective, the project team has provided its Conclusions and Recommendations to Ayotte Plumbing in Section 5 of this report.

## **4. Discussion**

### **4.1. Discussion on Ayotte Plumbing, Heating, and Air Conditioning**

#### **4.1.1. Situational Analysis**

Ayotte Plumbing has provided services throughout Southern New Hampshire and Northern Massachusetts since 1970. As the biggest spender at industry vendors in the market area, it can be assumed that Ayotte Plumbing owns a large part of the market share. Their customer base is largely residential with occasional commercial maintenance and repair operations. They don't seek new construction projects because the business for new constructions is completely different from repair jobs.<sup>3</sup>

New construction, and Maintenance and Repair (M&R) are two subsectors of the plumbing and construction industries. They are vital in controlling and maintaining the rapid technology advancements made all over the world in the past 15 years. In national income and expenditure accounts, new construction includes all activities that increase or alter the stock of facilities while M&R includes all activities that maintain or restore the existing stock of constructed facilities. The differences between new construction, and M&R can sometimes be confusing and are often treated differently. Under ordinary circumstances, new construction will add value to a property, repairs are typically considered a part of ordinary property maintenance and do not cause a change in the assessment, and remodeling. Depending on what type of repair is being implemented, repairs may result in an increased assessment.<sup>4</sup>

Ayotte Plumbing's culture has a more relaxed atmosphere than most plumbing companies because Ayotte Plumbing wants customers to trust employees before allowing them to enter into their homes. The company stresses personal experiences, which is the key to their success. By having experienced and knowledgeable field technicians, Ayotte Plumbing has built

over 40 years of success around a solid customer base. In addition to field technicians, the office staff and operations management have vast knowledge and experience that have allowed the company to function, adapt, and grow throughout its existence.<sup>3</sup>

While the company is strong in its knowledge of products, it does not always extend this knowledge to their customers. The company always wants to educate its customers in what is best for their homes and advise them away from services that are not necessary. This goal does not always translate into reality. Also, while the company should cater towards the existing customer network, it should be looking for opportunities that can increase its customer base and result in greater revenue. This includes more advertisements, tradeshow, and additional forms of outreach. These forms of marketing are known to draw in new customer segments as well as inform current customers about new services offered. The project team and sponsor felt that the 45 MG Thickness Gauge might help expand Ayotte Plumbing's potential customer base because it has the opportunity to entice new customers to Ayotte Plumbing. This product would attract new customers because this service is new to residential markets.

The market where Ayotte Plumbing could offer this technology is in existing residential buildings. Existing residential buildings often develop leaks within their water supply systems. Water damage can cost property owners thousands of dollars to tear out and replace, especially when mold is involved. Most or all of these damages stem from accidental release of water from pressurized sources. The top five areas of residential water damage with average costs according to the Insurance Institute for Business Home and Safety (IBHS) are:

Plumbing Supply System Failure	\$5,000*
Toilet Failure	\$5,500*
Water Heater Failure	N/A
Plumbing Drain System Failure	\$4,000*
Washing Machine Failure	\$5,300*
<b>*after deductible</b>	

**Figure 1:** Insurance Institute for Business Home and Safety Top Five Water Damage Costs<sup>1</sup>

Currently there are no other companies in the market of non-invasive pipe testing. This creates an opportunity for Ayotte Plumbing to capitalize on the market with a first mover advantage. A first mover advantage is when a company provides a unique service or product to its customers before any other competitors.

#### 4.1.2. SWOT Analysis

The SWOT analysis is used to help identify the strengths and weaknesses of Ayotte Plumbing, and the opportunities and threats of the industry.

<b>SWOT Analysis</b>	
<b>Strengths</b> Customer Loyalty Explains services to customers Competitive Pricing	<b>Weaknesses</b> Lack of Expansion Warehouse Organization
<b>Opportunities</b> Assumed Monopoly	<b>Threats</b> Plumbing Companies within MA/NH

**Figure 2:** SWOT Analysis

Ayotte Plumbing is very successful in terms of maintaining customers because it is very thorough in its services. Ayotte Plumbing is able to offer these services at competitive pricing while still taking the time to explain each change to the homeowner's house. The president of Ayotte Plumbing has mentioned that this focus on maintaining customer loyalty detracts from Ayotte Plumbing's ability to draw in new customers and expand its customer base. Another facet that may detract from the value of the company is the organization of its warehouse. When the project team was touring the office, the warehouse was only regulated through paper forms and was very inefficient. Tracking the service trucks and supplies that Ayotte Plumbing uses on daily jobs could be improved through a more efficient form of organization.

There are also a few opportunities and threats that Ayotte Plumbing should be aware of when considering the new Pipe Corrosion Inspection Service. The company has an assumed

monopoly because there are no other known companies that would offer this service. With this assumed monopoly, Ayotte Plumbing would need to be vigilant for other companies imitating this trend. Since there is minimal equipment necessary to begin offering this service, other companies may quickly adapt and duplicate the service.

#### 4.2. Discussion of Plumbing Industry

Plumbing usually deals with laying of pipe lines which provide a means of transportation for fluids. The plumbing industry is a basic and substantial part of every developed economy. This is due to the need for clean water, sanitary collection, and transport of wastes. Industry contractors install and maintain plumbing fixtures, fittings and equipment. Industry activities include work on household pipes and drains, installation of gas, cooking and heating, appliances, and work on bathroom, toilet fixtures and venting systems. Emergency repair work (particularly water pipe bursts) represents a significant source of industry revenue. Contractors may also supply plumbing appliances and coupling products for construction projects.<sup>5</sup>

According to the IBIS World Industry Report, the plumbing industry in the US primarily does installations of new systems and repairs to existing plumbing.<sup>5</sup> Ayotte Plumbing seeks to innovate within this industry, and provide an inspection service that may increase the number of repair jobs that they perform. The report also claims that “Plumbing services [have] shown incremental change over the long term...”.<sup>5</sup> The project team identifies this as an opportunity that Ayotte Plumbing could take advantage of. The fact that maintenance and repair work counted for 55% of nationwide industry revenue in 2013 is essential to understanding why Ayotte Plumbing seeks to increase the number of repair jobs that it has.

Demographics about the customer base for Ayotte Plumbing are difficult to research. Therefore, nationwide industry statistics gathered from the IBIS World report must suffice. The

report states that industry revenues are closely related to the construction industry and to the availability of disposable income for homeowners. The following figure shows the segmentation of the Plumbing Industry. Ayotte Plumbing currently deals mostly with existing residential buildings. This category along with existing commercial buildings accounted for 55.4% of the plumbing industries revenues in 2013.

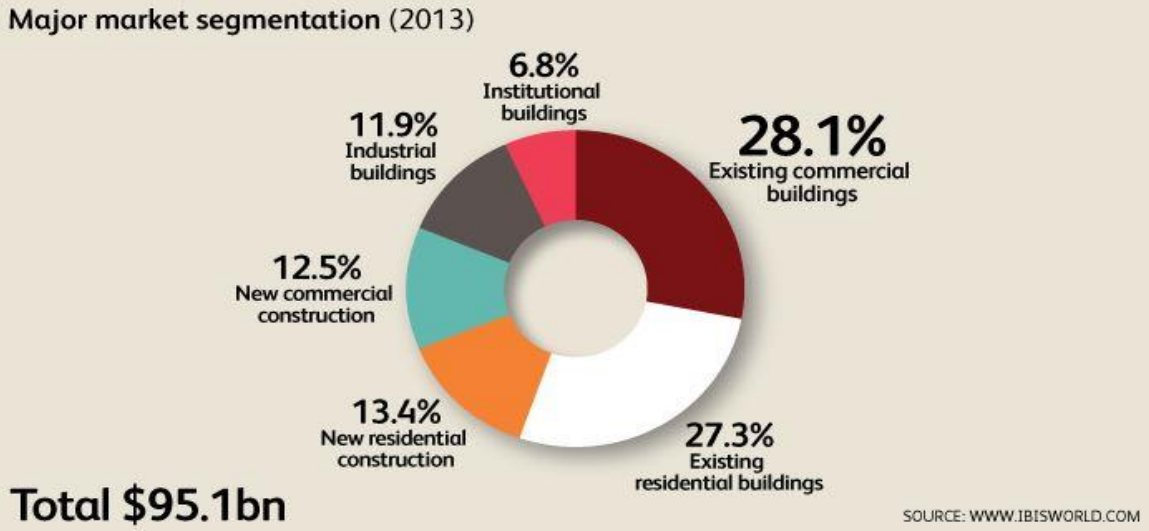


Figure 3: Major Market Segmentation<sup>5</sup>

#### 4.2.1. Cause of water supply leaks

Corrosion can happen in a water supply system sooner than the system's life expectancy. If changes such as discolored water, inconsistent water flow, or high water bills are noticed then one might be dealing with leaks in the water supply system. There are many factors, like the ones listed previously, that contribute to leaks in water supply pipes. The major contributing factors are:

<b>Factor</b>	<b>Description</b>
<b>Water pH rate</b>	The pH scale is used to identify the acidic or basic level of the water. The pH scale ranges from 0 to 14 where 7 is the neutral point; close to 0 is acidic, and closer to 14 is basic. Water that is not near neutral can cause corrosion
<b>Oxygen in the water</b>	Oxygen is responsible for metals degrading through the process of internal oxidation. This is a common issue with metal based water supply pipes
<b>Temperature of the water</b>	High temperature levels contribute to faster internal oxidation
<b>Velocity and water pressure</b>	High pressure and velocity causes turbulence which corrodes the inside of the pipe

**Figure 4:** Cause of Water Supply Leak<sup>6</sup>

#### 4.2.2. Residential and commercial piping materials

There are five major types of piping that are being used widely in residential and commercial properties, namely PVC, CPVC, PEX, and Copper. Below are overall descriptions and properties of each type.

##### **Polyvinyl chloride**

Polyvinyl chloride or PVC is commonly used for indoor water distribution due to its high resistance to corrosion and relatively low price, but the surrounding temperature must always be taken into consideration because PVC is very brittle at low temperatures and would



start to deform in temperatures above 140 degrees Fahrenheit. Consequently, PVC is not an ideal material for hot water distribution.

### **Chlorinated polyvinyl chloride**

Chlorinated polyvinyl chloride or CPVC was designed to overcome deformation in high temperature of PVC. As a result, CPVC can be safely used for hot water distribution and stronger than PVC, but CPVC is still suffer from brittleness and is more expensive.

### **Cross-linked polyethylene**

Cross-linked polyethylene or PEX is well known for its flexibility which results in improper fitting. PEX offers a great resistance against high and low temperatures. PEX is designed for indoor use and special coating is required for an outdoor use, but one must be wary of rodents because PEX is soft and can be easily damaged.

### **Copper**

Copper is widely used for water distribution both indoor and outdoor for many decades. Copper is highly durable and naturally prevents bacteria growth. Although copper has many advantages, it is very expensive and very sensitive to acidic water, which can expedite corrosion. Metallic taste in water is also common among copper water supply systems.

	<b>PVC (Polyvinyl chloride)</b>	<b>CPVC (Chlorinated polyvinyl chloride)</b>	<b>PEX (Cross-linked polyethylene)</b>	<b>Copper</b>
<b>Cost</b>	\$0.20/ft.	&0.83/ft.	\$0.46/ft.	\$3.90/ft.
<b>Max Service Temperature</b>	140 °F	200 °F	200 °F	200 °F
<b>Weight</b>	0.21 lbs./ft.	0.23 lbs./ft.	0.1 lbs./ft.	0.33 lbs./ft.
<b>Corrosion Resistance</b>	High	High	High	Medium
<b>Life Expectancy</b>	75-100 years	75-100 years	75-100 years	50-75 years
<b>Flexibility</b>	Low	Low	High	Low

*Figure 4: Residential and Commercial Piping Materials<sup>7, 8, 9, 10</sup>*

Research coupled with our sponsor’s expertise dictated that the project team focus on copper piping.<sup>10</sup> According to Ayotte Plumbing, they operate mostly in older housing, where copper pipes are common.

#### 4.2.3. Types of Non-invasive Inspection Tools

Various different techniques are used to solve the problem of corroding pipes and pipe leaks. While some techniques have certain advantages, most prove to be overly expensive and invasive. After conducting extensive research and working with our sponsor, the project team found the most affordable and reliable technologies are Ultrasonic testing and portable X-raying. Tangential X-rays provide only one "snapshot" of the pipe per location. As a result, performing a comprehensive examination for all of a facility’s piping is very cost-prohibitive. Despite X-ray technology seeming like a feasible option, X-ray involves radiation which can be left behind in the home, making it temporarily unsafe for families, especially those with children. A recent

method called X-Ray powder diffraction (XRD) is a fairly common technique performed on products that may erode. XRD is useful in identifying crystalline phases in unknown materials. The XRD technique takes a sample of the material and places a powdered sample in a holder, then the sample is illuminated with X-rays of a fixed wave-length and the intensity of the reflected radiation is recorded using a goniometer. The different intensities seen in the X-ray allow inspectors to determine the compounds currently in the pipe; knowing which compounds are present in the pipe is beneficial to understanding the extent of the corrosion reactions that have taken place. X-rays are more expensive and invasive than Ultrasonic testing. Additionally, performing X-ray inspections are extremely time consuming for larger projects.<sup>11</sup>

The project team decided that the best option was to use minimally invasive Ultrasonic testing. Ultrasonic testing is the examination of materials through high frequency sound waves. These waves are used to detect and evaluate flaws, measure dimensions, and characterize materials. The main functional units of Ultrasonic testing inspection systems are the, pulser/receiver, transducer, and display device. A pulser/receiver provides a system with high voltage electrical pulses and is categorized as an electronic device. A transducer provides the system with high frequency ultrasonic waves. The sound waves are sent through the material and are reflected back when there is discontinuity in the wave path. The reflected wave signal is then transformed into an electrical signal by the transducer and is displayed on the screen with the measured wall thickness.<sup>12</sup>

Ultrasonic testing has many advantages in comparison to other nondestructive testing methods. Ultrasonic testing works best in discontinuous detection of surface and subsurface measurements. The depth of penetration for flaw detection and measurement is superior to other nondestructive testing methods. Reflector positioning and estimation of the size and shape of

flaws is more accurate when done with Ultrasonic testing. When one is performing nondestructive testing, only a single side of access is necessary to get a reading. The technology of Ultrasonic testing allows for compact and easy to use equipment.<sup>13</sup>

There are some limitations of Ultrasonic testing that must be noted. The testing surface must be accessible by the ultrasound device. Some materials that have rough, very small, thin, or heterogeneous surfaces make it difficult to utilize Ultrasonic testing. Coupling medium must be applied to the surface before testing. Equipment calibration and the characterization of flaws need reference standards for the most accurate results. The Ultrasonic testing practitioner must be properly trained in order to perform the test effectively.<sup>12</sup>

#### 4.2.4. Monopoly

Monopolies occur when a company has a large majority of the market or the market requires such specific qualifications that only a small few are able to enter into the market. Ayotte Plumbing would enter into an assumed monopoly because at present there is no one else in the market publicly offering these services. While this service is offered on the large-scale to commercial factories, it is not available to residential sectors and it is not offered to smaller companies. This would grant Ayotte Plumbing a great opportunity to capitalize on this market and gain customers before competitors join the market.<sup>12</sup>

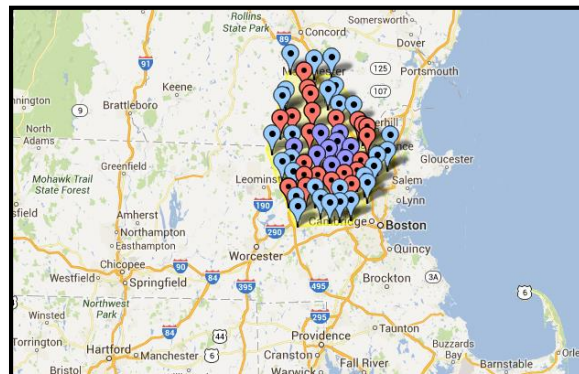
### 4.3. Discussion of Marketing

#### 4.3.1. Market Segmentation

In order to determine the size and scope of the market, the team gathered information concerning primary, secondary, and consumer sales volume from Ayotte Plumbing's sales records. These sales were primarily located in Northeast Massachusetts and Southeast New

Hampshire. These locations have large numbers of older houses in which the plumbing is wearing thin and thus more prone to leaks.

Figure 5 denotes the physical representation of the market that Ayotte Plumbing services. There are 31 primary locations for sales and 29 secondary locations. Of the 31 primary locations, 9 of them make up the majority of sales for Ayotte. These locations are (in decreasing sales volume): Chelmsford, Westford, Billerica, Lowell, Tewksbury, Dracut, Tyngsboro, Carlisle, and Groton. Purple markers denote a location that has one of the largest sales volumes, red markers denote when the location is a primary market for Ayotte Plumbing, and blue markers denote when the location is a secondary market.



**Figure 5: Ayotte Plumbing Sales Locations**

#### 4.3.2. Marketing Mix

The new service that would be marketed, if Ayotte Plumbing chooses to act on this opportunity in the future, is a Pipe Corrosion Inspection Service. Ayotte Plumbing could utilize the 45MG Thickness Gauge in order to perform this service. Upon a request for the service, an employee from Ayotte Plumbing would go to the address provided by the customer and perform

an inspection of as many water supply pipes as is deemed necessary. The employee would have an in-depth understanding of the device and would be able to identify potential problem areas in exposed piping. The service should be marketed to new and repeat customers alike.

Customers should see value in this service, but successful marketing techniques would entice new customers, more customers, and a greater volume of customers than if there was no marketing were done. New customers may require more information about the benefit of this service to reach a purchase decision. These new customers may not have had any issues with piping before, so the promotional efforts should be focused on preventative measures. The core value that is being provided is a sense of security through knowledge. If a customer *knows* that within some time frame their pipes may fail, then that customer will have a level of preparedness when the pipe does leak. This knowledge would allow customers to prepare financially, and this lends itself to a general feeling of safety because the customer is aware of the issue. Feedback and responses from customers would be critical.

This feeling of security is one of the factors that would make this product feasible for Ayotte Plumbing. Since other companies do not have the capabilities that Ayotte Plumbing would possess, the device would give them a competitive advantage. In order to begin sales of the Pipe Corrosion Inspection Service, Ayotte Plumbing would require an investment of around \$3,000. This amount would include purchasing the 45 MG Thickness Gauge and initiating marketing and advertising procedures.

Historically, most marketing efforts for Ayotte Plumbing have been image related. Recently, the company has started newsletters and discount offers to add to its marketing efforts. Also, the company is supplementing its online image with direct mail. This defies current trends, but sending information in the mail is a niche that competitors may not have.

If purchased in the future, the 45 MG should not be advertised too aggressively in newsletters, discount offers, or online campaigns. These areas of marketing should be focused on secondary customers since primary customers already have contact with the business. During contact with the field technicians, primary customers would be informed of the new service. The secondary customers would additionally be reached through tradeshow and other forms of advertising. The employee's ability to talk and be personable with all customers builds trust that would contribute to the decision to purchase this service. The price of the possible inspection service should be compared against the potentially high cost of water damage when it is pitched to the customer.

Ayotte Plumbing could use the competitive advantage of being the only company in leak detection/prevention as a tool to bring in new customers. This could be promoted in things like tradeshow, newspaper articles, etc. For the tradeshow, having the central focus of the booth be around what the propose service is, and having side sections of the booth cater towards the other parts of the company, would attract interest. This would allow knowledge of the service to get around and intrigue those whom have never heard of the concept before. Also, if the company decided to get a newspaper article written about 'Leak Detection/Prevention in the Residential Sector', it would reach many home owners that Ayotte Plumbing is not currently in contact with.

#### 4.4. Discussion of Methods

Initially, the general project description was for the project team to create a non-invasive detection technology. This technology would test a copper pipe's inner wall thickness. The ultimate goal was to make a determination on when a given pipe would fail, which means developing leaks. The project team selected several research topics related to this project description and initiated literature research to gain a better understanding of the project. The

main areas of research included in-home copper water-supply pipes, current methods of leak detection, and technology associated with fixing these issues. Through this research, the project team discovered that products satisfying the objectives were already in existence.

#### 4.4.1. Product Review

Figure 6 is a breakdown of the six categories that are used to identify the usefulness and practicality of the products that the project team had looked into. These categories are based on the project sponsor’s specifications for the project.

<b>Products</b>	<b>Quality</b>	<b>Price</b>	<b>Success Rate</b>	<b>Simplicity</b>	<b>No Training Required</b>	<b>Multiple Result Forms</b>	<b>Total</b>
<b>45 MG</b> <i>Thickness Gauge</i>	+	o	+	O	+	+	4
<b>EPOCH 600</b> <i>Flaw Detector</i>	o	o	o	O	o	o	0
<b>26 MG</b> <i>Thickness Gauge</i>	-	+	o	+	+	-	1

**Figure 6:** Product Decision Matrix

In order to determine the success of each product, there are three categories each specification can be placed in. These categories are ‘Successful’, ‘Passable’, and ‘Not Acceptable’. ‘Successful’ is denoted by a plus sign (+) and is filled in with a green color. This category is when the product is very effective and efficient for Ayotte Plumbing. ‘Passable’ is denoted by a zero (o) and is filled in with yellow. ‘Passable’ is when Ayotte Plumbing is able to



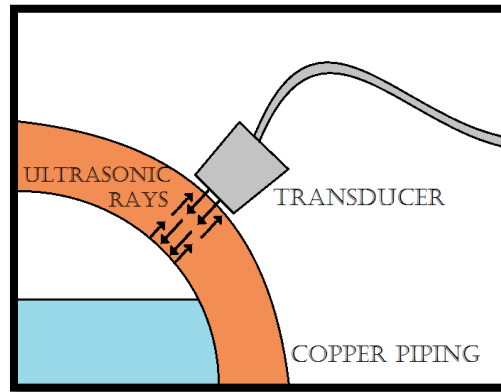
use the product specification, but the product does have flaws in the specification. For example, the EPOCH 600 Flaw detector requires little training, but the training is not intensive and significant enough to warrant a 'Not Acceptable' as its qualification. 'Not Acceptable' is denoted by a minus sign (-) and is filled in with red. 'Not Acceptable' is when the product cannot fulfill the specification to any degree and, thus, is a negative for Ayotte Plumbing when deciding which product to use.

When the project team was tabulating the results, 'Successful' was counted as a plus one, 'Passable' as a zero, and 'Not Acceptable' as a minus one. The totals above show that the 45MG Thickness Gauge has the best score, earning a score of four. This means that the best product Ayotte Plumbing could use to satisfy the needs of their customers is the 45MG Thickness Gauge.

During literature research, the project team concluded that while no plumbing companies offer this service, there are a number of technologies already on the market that could fulfill the project objectives. The necessary functionalities of the instrument are being non-invasive (i.e. may not cut out sections of piping) and the ability to measure wall thickness. The updated objectives for the completion of the project are to find a suitable technology/instrument and to provide information that would assist with the implementation of said technology into a service that could be provided by Ayotte Plumbing, if the company decides to purchase the instrument in the future.

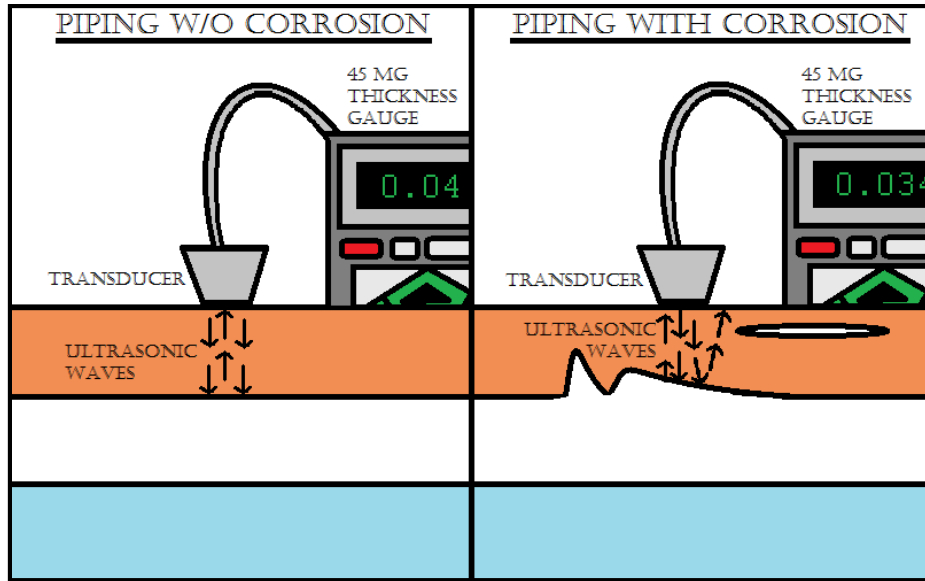
The operational process of this service is to compare the original wall thickness with the current wall thickness. An operator knows the starting wall thickness, based on the pipe diameter. An instrument can be used to determine the current wall thickness. A comparison would be made between the starting thickness, the corroded (measured) thickness, and the

number of years the system has been in use. These numbers can be used to estimate the remaining useful life of the pipe(s).



**Figure 7:** Ultrasonic Thickness Gauge Measuring Wall Thickness

The Olympus Corporation has an informational pdf for the 45MG Thickness Gauge that is accessible online; the project team could not include this file into our Appendices because of copyright issues. The manual provides specifications, instructions, and information necessary to utilize the product. The 45MG Thickness Gauge satisfies all needs of the project and it is possible to successfully implement for any plumbing company.



**Figure 8:** 45 MG Thickness Gauge Testing Process

When operating the 45 MG Thickness Gauge, the tester must use a reference page in order to determine the acceptable width for the piping and to determine whether the piping needs immediate removal. The reference page must provide starting pipe thicknesses for all pipes that are used in housing facilities. This reference page is coupled with the 45 MG Thickness Gauge's results in order to determine if the pipes need replacement. The 45 MG Thickness Gauge determines the width of the piping by inputting the frequency of sound for copper (3500m/sec) and then sending a wave of that frequency through the piping. These ultrasonic waves bounce back after hitting a surface that is no longer that frequency of sound. The transducer then receives the wave back and calculates the time it took to travel from the outer diameter to the inner diameter and back. This time multiplied by the frequency of sound calculates the thickness of the copper pipe. The generic equation is:

$$2 * \text{Thickness} = \text{Frequency} * \text{Time}$$

For example, if the piping were a ½” Type L Copper Piping, the starting wall thickness would be 0.040 mm and the time it would take to travel back and forth from the transducer would be  $2 * 0.04\text{mm} = 3500\text{m/s} * t$ , thus  $t = 2.2857 * 10^{-7}$  seconds.

There are minor issues with this test when attempting to receive consistent measurements on corroded copper piping. This lack of consistency is due to the transducers inability to be perfectly perpendicular to the piping’s inner diameter when the tester is conducting the tests. When the transducer is not perpendicular with the piping, some of the ultrasonic waves may not send back an accurate response, creating inconsistent measurements and wave results. This inconsistency can still yield a reading, but multiple tests on the same spot will give a more confident and precise pipe-thickness measurement.

If the 45 MG Thickness Gauge does not read out a response, then the copper piping is too corroded and pitted to receive waves back into the transducer. Alternatively, no response will be given if the pipe is below the 45 MG Thickness Gauge’s minimum tolerance. These are warning signs that that the piping needs replacement immediately.

#### 4.4.2. Sponsor Interactions

Dean Ayotte, the owner of Ayotte Plumbing, was the project sponsor and had the original thought for this project. The first visit to Ayotte Plumbing was for a demonstration of the products. The 45MG device was selected as more reliable, and a consequent visit to Ayotte Plumbing was to learn how to operate the product. At the product demonstration, the devices did not seem to be functioning properly, and it was determined that a different transducer would be required to make them more accurate. The correct transducer was brought to the product training, and everyone present took measurements on both new and corroded pipes. The project sponsor

learned the product well enough to teach his own employees about how the service would operate.

Concluding interactions were arranged among the project team, sponsor, and advisor. The purpose of the final interaction was to exchange knowledge and inform the project sponsor of conclusions/recommendations.

#### 4.4.3. Vendor Interactions

The project team found a company with a suitable technology and instruments, Olympus NDT. The project team considered Olympus's Flaw Detectors and Thickness Gauges. Olympus's Flaw Detectors provided many more capabilities than necessary, and were expensive. The Thickness Gauges satisfied the needs of the project while remaining at a reasonable price for Ayotte Plumbing.

The Olympus Corporation is an international manufacturer of many diverse instruments for markets such as Medical, Life Sciences, Camera & Audio, and Industrial. This corporation is well established, founded October 12, 1919, and has recently adapted to assume more social responsibility. They are embracing the three "social IN's", *Integrity*, *Innovation*, and *Involvement*. This acceptance of social responsibility is a new trend in business, and seems to indicate that the Olympus Corporation is reputable and forward-looking.<sup>15</sup>

The products suggested by Olympus were the EPOCH 600 Flaw Detector, 26MG and 45MG Thickness Gauges. Olympus demonstrated these products to Ayotte Plumbing and the Project Team in order to ascertain the functionality of the product alternatives. A trial period from February 7- April 4, 2014 was arranged by Paul Mespelli for Ayotte Plumbing to test the 45 MG Thickness Gauge.

#### 4.4.4 Realtor Interactions

The project sponsor saw the value of interacting with Real Estate Agencies to determine if the proposed service could provide knowledge to homeowners. Conveniently, a project team member already had a close relationship with a Realtor. Colleen Kilfoil is a Broker/Owner of ACapeHouse.com, a real estate agency operating primarily on Cape Cod and the South Shore of Massachusetts.

Colleen revealed a lot of valuable information. She believed that the service would be extremely useful for any clients looking to purchase a foreclosure home. Homes that have been foreclosed upon are typically left in a state of neglect, including the piping. She recalled one experience where a client had purchased a foreclosure home, turned the water on, and had people stationed around the house watching for leaks to occur. In this particular case numerous leaks were found and it delayed the move-in date for her client. If a Pipe Corrosion Inspection Service were available to the residential market, this client could have prevented that entire situation from occurring. Also, the plumbing company could have benefited from inspecting the piping and replacing any areas that were compromised.

Colleen also informed the project team of a similar service being implemented in a different industry. The TankSure Program "...is the only Proactive Tank Replacement Process available for residential heating oil tanks."<sup>16</sup> Using ultrasonic testing, Boston Environmental has created this program that successfully brings value to Home Comfort Service Providers, Homeowners, Realtors, Insurance Companies, and Home Inspectors. This program shows that it is possible to implement ultrasonic technology to non-invasively test within a residential market.

## **5. Conclusions and Recommendations**

The greatest limitation identified in this project has been communication. The change from *creating* a technology to *finding* a suitable technology took time to communicate to and convince the project sponsor. The project sponsor gave consent to proceed, and an explanation of viable technologies can be found in the Product Review (4.5.2).

Since it has been decided that Ayotte Plumbing will not currently be moving forward with the purchase of the 45MG Thickness Gauge, we recommend that a survey be conducted to see if Ayotte Plumbing's customers are interested in a product that would satisfy the goal of leak prevention. Ayotte Plumbing currently deals mostly with existing residential buildings, and should consider expanding into existing commercial buildings. Additionally, we recommend that Ayotte Plumbing begin talking to an insurance company to see if flaw detection is a viable service to create within the insurance industry.

The most positive conclusion that can be made from this project is that Ayotte Plumbing is a successful company that does not require any new services to continue operations. The company is well established within their region, and can rely on brand recognition to earn work. Ayotte Plumbing's culture is that of a family; customers trust its employees enough to leave the house even while an employee is still working inside it. The Ten Core Values (Appendix 7.2) of Ayotte Plumbing have created a company culture that resonates with its customers and keeps them coming to Ayotte Plumbing whenever they have any plumbing related issues.

Other recommendations for the company include 'going green'. It is noted that the U.S. Plumbing Industry has been trending towards environmental friendliness.<sup>5</sup> Promotion of activities that are done in an effort to reduce Ayotte Plumbing's environmental footprint should attract new customers, or generate enhanced loyalty from repeat customers. Attracting new

customers should be a relatively high priority for the company, as one can only repair the same homes so many times.



## **6. References**

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- <sup>2</sup>Joseph, King. *Disaster Safety* Web. 19 Feb 2014.
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- <sup>7</sup>"Home Improvement: Eight Types of Water Supply Pipes." *Yahoo Contributor Network*. N.p., n.d. Web. 14 Feb. 2014.
- <sup>8</sup>"PEX Information." *PEX Information*. N.p., n.d. Web. 14 Feb. 2014.
- <sup>9</sup>"What is CPVC Pipe?" *wiseGEEK*. N.p., n.d. Web. 14 Feb. 2014.
- <sup>10</sup>"The Advantages and Disadvantages of Different Residential Plumbing Materials." *HubPages*. HubPages, n.d. Web. 27 Mar. 2014.
- <sup>11</sup>Eckert, Richard (2003). *Field Guide for Investigating Internal Corrosion of Pipelines*. NACE International

<sup>12</sup>"Introduction to Ultrasonic Testing." *Introduction to Ultrasonic Testing*. N.p., n.d. Web. 7 Apr. 2014.

<sup>13</sup>"ULTRASONIC & ADVANCED ULTRASONIC TECHNOLOGY." *MISTRAS NDT Products & Systems*. N.p., n.d. Web. 7 Apr. 2014.

<sup>14</sup>"Monopoly." *Gale Encyclopedia of American Law*. Ed. Donna Batten. 3rd ed. Vol. 7. Detroit: Gale, 2010. 109-112. *Opposing Viewpoints in Context*. Web. 7 Apr. 2014.

<sup>15</sup>"Olympus Your Vision, Our Future." *Olympus Corporation* N.p., n.d. Web. 9 Oct. 2014.

<sup>16</sup>"Welcome to the TankSure Program." *Boston Environmental*. N.p., n.d. Web. 17 Apr. 2014

## **7. Appendices**

### **7.1 Authorship Page**

Our project team consisted of four members: John Kilfoil, Melissa Cowan, Ryan Kolb, and Sitthipat Preedawan. Group members shared responsibilities and concentrated on specific topics throughout the project.

1. **Problem Statement:** Ryan Kolb and John Kilfoil

2. **Materials & Methods:** John Kilfoil

3. **Results:** Melissa Cowan, Ryan Kolb, John Kilfoil, and Sitthipat Preedawan

4. **Discussion:** Melissa Cowan, Ryan Kolb, John Kilfoil, and Sitthipat Preedawan

4.1.1. **Situational Analysis:** Ryan Kolb, Sitthipat Preedawan, John Kilfoil

4.1.2. **SWOT Analysis:** Melissa Cowan and Sitthipat Preedawan

4.2. **Discussion of Plumbing Industry:** John Kilfoil and Ryan Kolb

4.2.1. **Cause of water supply leaks:** Sitthipat Preedawan

4.2.2. **Residential and commercial piping materials:** Sitthipat Preedawan

4.2.3. **Types of Non-invasive Inspection Tools:** Ryan Kolb, John Kilfoil, and Sitthipat Preedawan

4.2.4. **Monopoly:** Melissa Cowan

4.3. **Discussion of Management/Marketing:** Melissa Cowan

4.3.2. **Market Segmentation:** Ryan Kolb

4.3.3. **Marketing Mix:** John Kilfoil

4.4. **Decision Matrix for Products:** Melissa Cowan

4.4. **Methods:** John Kilfoil and Melissa Cowan

4.4.1. **Product Review:** Melissa Cowan and John Kilfoil

4.4.2. **Sponsor Interactions:** John Kilfoil

4.4.3. **Vendor Interactions:** John Kilfoil

4.4.4. **Realtor Interactions:** John Kilfoil

5. **Conclusions and Recommendations:** John Kilfoil and Melissa Cowan

6. **References:** Sitthipat Preedawan and Ryan Kolb

7. **Appendices:** Ryan Kolb and John Kilfoil

## 7.2 Ten Core Values used at Ayotte Plumbing

1. **Customer First:** Customer Satisfaction is our top priority.
2. **Excellence:** We strive for excellence in everything we do.
3. **Perseverance:** We do not stop until the job is done right.
4. **Enthusiasm:** We approach each day with energy and excitement.
5. **Creativity:** We delight in being different from the rest.
6. **Pride:** We derive great satisfaction through our accomplishments.
7. **Integrity:** We adhere to the highest ethical standards.
8. **Recognition:** We acknowledge the contributions of our employees.
9. **Sharing:** We share our success with everyone who contributes to it.
10. **Fun:** We celebrate our accomplishments.