2019 Washington Street, East
Charleston, WV 25305
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West Virginia Purchasing Division

The following documentation is an electronically-submitted vendor response to an advertised solicitation from the *West Virginia Purchasing Bulletin* within the Vendor Self-Service portal at *wvOASIS.gov*. As part of the State of West Virginia's procurement process, and to maintain the transparency of the bid-opening process, this documentation submitted online is publicly posted by the West Virginia Purchasing Division at *WVPurchasing.gov* with any other vendor responses to this solicitation submitted to the Purchasing Division in hard copy format.

Solicitation Response(SR) Dept: 0211 ID: ESR02142300000003772 Ver.: 1 Function: New Phase: Final

Modified by batch , 02/14/2023

Header 1

List View

General Information | Contact | Default Values | Discount | Document Information | Clarification Request

Procurement Folder:	1165807
Procurement Type:	Central Contract - Fixed Amt
Vendor ID:	000000229419
Legal Name:	MILLER ENGINEERING INC
Alias/DBA:	
Total Bid:	$0.00
Response Date:	02/14/2023
Response Time:	10:15
Responded By User ID:	MillerEngineer1
First Name:	Travis
Last Name:	Taylor
Email:	ttaylor@millereng.net
Phone:	304-291-2234

SO Doc Code:	CEOI
SO Dept:	0211
SO Doc ID:	GSD2300000007
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Solicitation Description:	Campus Chill Water Loop / Plant Evaluation and Enhancements
Total of Header Attachments:	1
Total of All Attachments:	1

Department of Administration
Purchasing Division
2019 Washington Street East
Post Office Box 50130
Charleston, WV 25305-0130

State of West Virginia
Solicitation Response

Proc Folder: 1165807

Solicitation Description: Campus Chill Water Loop / Plant Evaluation and Enhancements

Proc Type: Central Contract - Fixed Amt

Solicitation Closes	Solicitation Response	Version
2023-02-14 13:30	SR 0211 ESR02142300000003772	1

VENDOR
000000229419
MILLER ENGINEERING INC

Solicitation Number: CEOI 0211 GSD2300000007

Total Bid: 0 **Response Date:** 2023-02-14 **Response Time:** 10:15:26

Comments:

FOR INFORMATION CONTACT THE BUYER
Melissa Pettrey
(304) 558-0094
melissa.k.pettrey@wv.gov

Vendor Signature X **FEIN#** **DATE**

All offers subject to all terms and conditions contained in this solicitation

Line	Comm Ln Desc	Qty	Unit Issue	Unit Price	Ln Total Or Contract Amount
1	Campus Chill Water Loop / Plant Evaluation				0.00

Comm Code	Manufacturer	Specification	Model #
81101508			

Commodity Line Comments:

Extended Description:

Campus Chill Water Loop / Plant Evaluation

Expression of Interest

West Virginia –General Services Division

Campus Chilled Water Loop / Plant Evaluation

CEOI GSD2300000007

February 14th, 2023

Department of Administration
Purchasing Division
2019 Washington Street East
Charleston, WV 25305-0130

304-291-2234 (ext. 107) | 54 West Run Rd. | Morgantown, WV 26508 | www.MillerEng.net
West Virginia | Pennsylvania | Maryland | Ohio| Virginia

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The Miller Engineering Difference

We are very pleased to submit our response for the GSD Campus Chilled Water Loop Project. MEI will serve as the prime consultant for the Project. We regularly performs as a prime consultant for multiple clients including for the state of West Virginia. MEI is currently the acting prime consultant for GSD projects including the Elevator Modernizations Project and HVAC Upgrades to WV Buildings 25 and 54 currently in bidding and construction respectively. We recently completed the Capitol Complex Central Chiller Plant Modifications Project. We have previously delivered several projects including the Building 5 Freight Elevator Project, Design of an HVAC Replacement for Building 36, Covid-Related Evaluations of Buildings, and B22 Second Floor HVAC Modifications.

We're not your typical MEP firm; we ensure our designs meet very specific, time-tested criteria, including but not limited to being constructible, operable and maintainable. Based on the EOI, we see those methodologies as valuable to GSD on the project. Our hands-on staff takes great pride in their construction and operations backgrounds, which helps visualize the project as it would be built instead of just lines on paper. We perform takeoff level cost estimating whenever possible and some level of commissioning occurs on each project, due to our "boots on the ground" construction administration approach.

As we primarily work in facilities renovations, MEI has worked on many chilled and hot water systems over the years, with many different configuration. Craig brings a working knowledge of loops systems based on work at such facilities as Pipestem lodge, in which he took separate chilled and hot water systems and created a loop configuration, which increased efficiency and redundancy. His work on campus loops at WVU and Uniontown Hospital as in-house Engineer brings a real world operation knowledge of the concerns and complexities associated with these systems. To assist Miller Engineering with the evaluation of the existing piping system, we have teamed with CoorView Pipe Inspection and Testing. They bring extensive knowledge and experience in the evaluation of piping systems, having been in business for over 40 years. One only need speak with Bill Duncan, President, to appreciate the depth of knowledge and commitment he brings to bear on the project. We have also asked Dr. Ken Means, retired WVU faculty, to bring his significant knowledge and experience to the project as a resource. Ken is well known for decades of work in energy efficiency and the evaluation of HVAC systems and components.

We believe our previous experience with the Chiller Plant in the recent Renovations Project makes MEI an excellent choice for this project. We were the prime consultant on the project, which made the most significant alterations to the plant since its construction. These included the installation of 1MW generators to drive chillers, a controls upgrade, construction of a new thermal exchange building for switchgear and a water side economizer which required significant piping changes within the plant. During the project, we reviewed the campus loop in general and created a cooling load model of the campus. We also worked on the reconfiguration of the alternate power feed to the plant. Our past experience provides us with initial working knowledge of the campus, construction, and daily operations. This allows us to "hit the ground running" in the evaluation phase, and significantly increase our knowledge base of the campus chilled water system, resulting and a clear path forward to meet the project goals.

MEI would like to thank you for the opportunity to submit on the GSD Campus Chilled Water Loop Project. We wish you best of luck on the project and hope to speak with you in the near future.

Best regards,

Craig Miller
President/Owner
Miller Engineering, Inc.

TAB 1 – FIRM PROFILES

Firm Profile

MILLER ENGINEERING is a solely held (S) corporation owned by Craig Miller PE, President. The corporation maintains a Certificate of Authority with the WV State PE Board and has carried professional liability insurance since its inception. Neither the firm nor its professional engineers have ever faced disciplinary action in any form from the states in which they are registered.

Our engineered solutions involve a detailed assessment process. We approach each and every project with the guiding principle that buildings are designed to be livable and function in their intended purpose with reasonable maintenance.Neither the firm nor its professional engineers have ever faced disciplinary action in any form from the states in which they are registered.

Over the past 18 years Miller Engineering, Inc. (MEI) has engineered solutions in MEP system upgrades, repairs and renovations for projects of all scopes and sizes, with clients ranging from private owners to local and state governments. With a strict attention to detail and commitment to delivering a job done well and done right the first time, every time, ***MEI has accumulated a change order percentage of less than 0.1% over the past 10 years****.*

Our team has unique skill-sets regarding engineered renovation solutions. Each member of the team has hands-on mechanical system experience including installation, construction, design and facilities operations. Miller Engineering takes pride in being ***different by design****, and that difference shines through in all phases of our work and continued relationships with our clients.*

Additional Benefits

- Experienced and Licensed Professional Engineers
- Quality, Value-Engineered Project Delivery
- Qualified Construction Representative on Staff
- LEED-AP Certified
- Below Industry Change Order Status
- Building Information Modeling
- Interactive Solutions Provider
- Emergency Facility Response

Engineering Design and Consultation

- Mechanical
- Electrical
- Plumbing
- HVAC Design
- Renovation
- New Construction
- Building Information Modeling

HVAC Design
Commerical, Institutional
Educational
Bldg, and District Chiller Plants
Plumbing and Piping

Construction Administration
Maintenance/Facility Plans
Contract Administration
Code Observation

Communication System
Intercomm & Public AddressVoice/Data/CATV

Energy
Power Supply (Main/ Standyby)
Green & Renewable Consulting
Systems Utilization & Upgrades
Emergency Power systems

Facility Utilization
Energy Conservation Projects
Adpative Re-use
Planning/Life-Cycle Control
Engineered Replacement
Life Safety, Fire Alarm/ Sprinkler
Access Control
Emergency Response

Industry Experience
Education
Local & State Government
Commercial Development
Healthcare
Department of Parks & Recreation
Industrial

CorrView International, LLC
P.O. Box 8513 * Landing, NJ 07850 * Tel: 973.770.7764
info@corrview.com * www.corrview.com
January 26, 2023

Work History Background And Statistics

This automatically generated business resume is based upon our latest database of completed ultrasonic pipe testing projects, and is current as of January 20, 2023.

CorrView International, LLC has been involved in the field of corrosion control since 1981, and in the science of ultrasonic piping assessment since 1994. Over the past 28.8 years, we have conducted 1,156 formal ultrasonic investigations involving 88 different categories of piping system from condenser and chill water, to domestic water, to fire protection. We have evaluated 3,021 separate piping systems, addressed 65,764 individual sections of pipe, and have taken 882,338 thickness measurements for record - over 5,029,327 thickness measurements in all. Our findings have saved clients tens of millions of dollars by both predicting and preventing failures in time to effect repairs, as well as by retaining good quality pipe for future service. In those cases where we have identified fire protection systems with sufficient iron oxide rust deposits to completely stop all water flow - lives may have been saved.

Our business objective is to always provide the most useful and informative ultrasonic evaluation possible; producing independent, verifiable, *"black or white"* results. Excellence and integrity are paramount, with each ultrasonic report providing a thorough, accurate assessment of piping conditions. Rather than presenting a nearly worthless spreadsheet of a few wall thickness measurements *(often inaccurate)*, we provide the hard factual data required to answer critical decision making needs. Average and lowest wall thickness, average and maximum corrosion rates, percentage of allowable loss, years of remaining service life, summary graphs, and a priority repair listing represent only some of the useful statistical data typically provided. Sample reports are available at request.

Where severe corrosion problems threaten safety and operating capabilities, CorrView International can provide the hard documentation and recommendations needed to support the correct decisions. We provide our services to building owners, mechanical consulting engineers, real estate management firms, and government agencies throughout the United States, and pursue every ultrasonic project as a forensic investigation.

Located in New Jersey, we provide services primarily to the New York City area, and the Boston to Washington, D.C. corridor. We have investigated building properties in 256 different cities throughout 43 states; with work performed from Anchorage, Alaska to San Juan, Puerto Rico and the island paradise of St Thomas, U.S. Virgin Islands. Frequent cities of interest are San Francisco, Dallas, Houston, Los Angeles, Chicago, Atlanta, and Miami. Our furthermost investigations have been in Australia's Northern Territory and the Western Pacific island of Guam. Ultrasonic testing has also been provided in Canada and the Middle East through our association with local ultrasonic affiliates in those areas.

We provide a valuable source of information related to ultrasonic testing and corrosion on our Internet site at: **www.corrview.com**. We also offer a series of useful and informative Technical Bulletins regarding various corrosion and piping issues, sample test reports, published articles, as well as an extensive photo gallery illustrating different corrosion failure types.

Our primary goal continues to be excellence in every endeavor. Fees are reasonable and competitive, with our ultrasonic analysis of 50-60 examples of piping typically equal to or less than the cost to cut out and lab test just one pipe section. Please contact CorrView International, LLC at any time for further information.

Sincerely yours,

William Duncan
President, CorrView International, LLC

MILLER ENGINEERING

Craig Miller, PE	President, Principal in Charge
Travis Taylor, PE	Lead MEP Engineer
Tyler Trump	Designer
Jack Jamison	Code Review

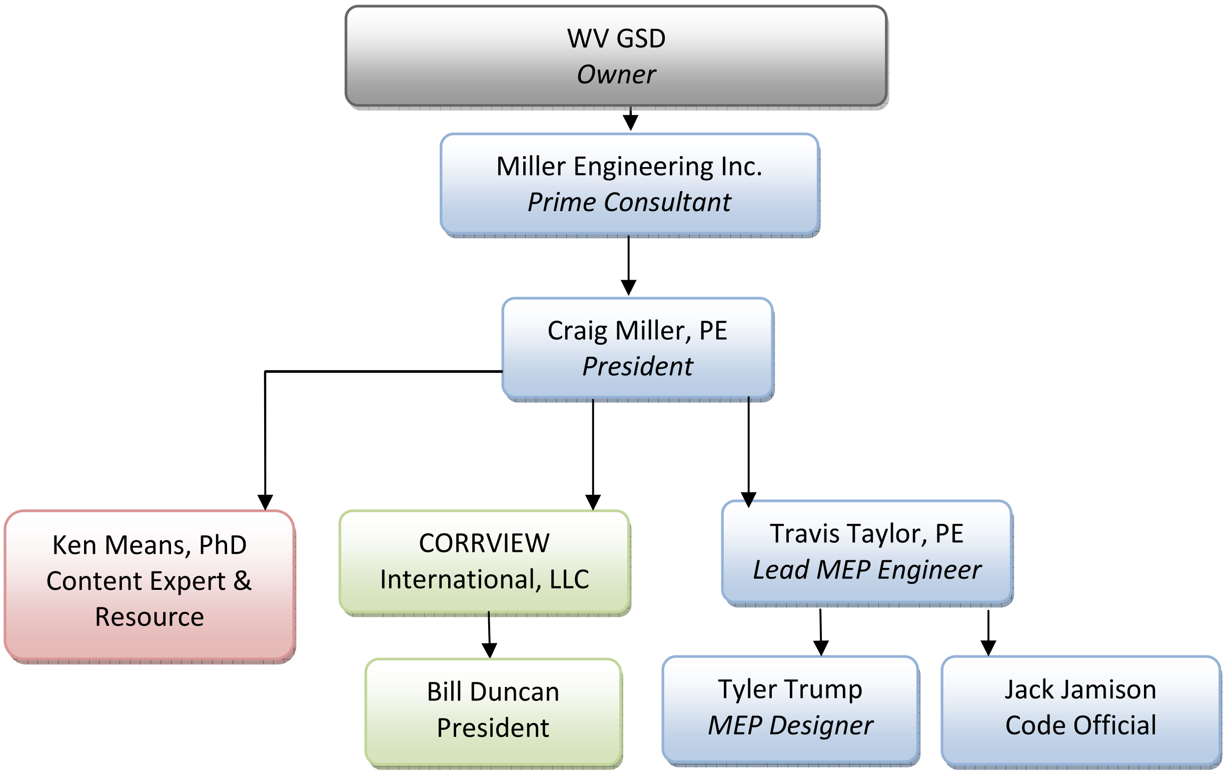
CORRVIEW INTERNATIONAL, LLC

Bill Duncan	President

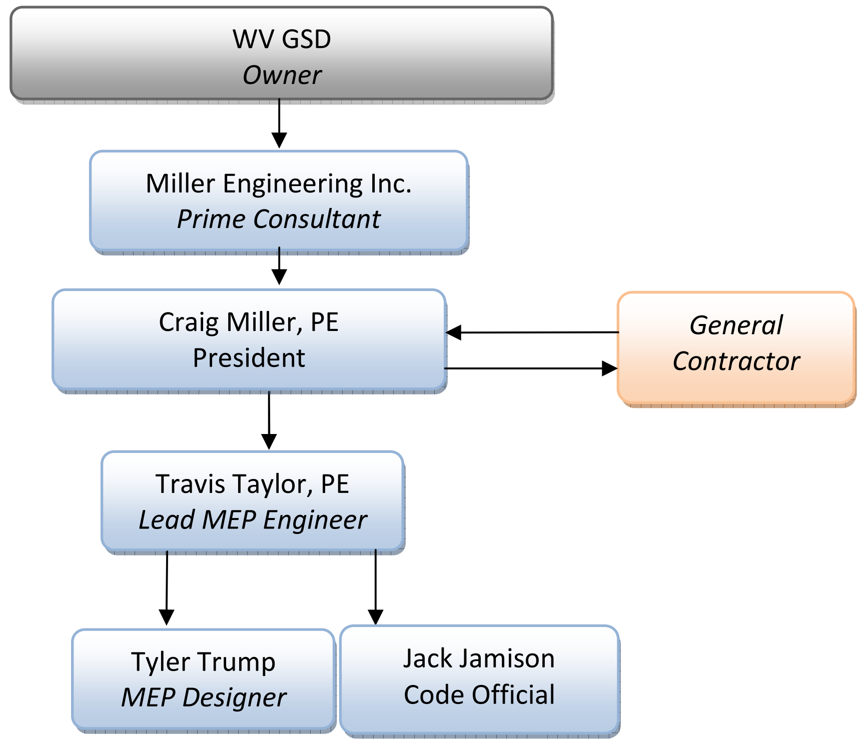
OTHER RESOURCES

Ken Means, PhD	Content Expert Resource

Organization Chart -Design



Organization Chart – Construction



TAB 2 – GOALS

Chilled Water Loop/ Plant Evaluation and Enhancements
Project Goals

PROJECT GOALS

Miller Engineering has reviewed the project description under Section Three of the Expression of Interest and offers the following outline of goals based in project approach concepts, methodologies, core-values, and prior pertinent experience. Please note that the project data sheets in Section four (4) further describe many of the projects referenced in this section.

Goal 2.1.1 – Evaluate Water Delivery to Buildings

A significant portion of MEI's projects revolve around renovations. Many of those renovations involve upgrades to the facilities chilled water and piping distribution systems. In many cases those systems are configured in a "loop" configuration with multiple sources, loads, and pumps, much like the Campus chilled water loop. MEI has successfully completed many chilled projects using such system configurations using various pumping strategies. Craig has not only designed but has evaluated, operated, and maintained such systems at WVU and Uniontown Hospital. He brings that operations knowledge to this project. We have a history with the both the chilled water plant, and the chilled water loop, which will permit us to "hit the ground running" on the evaluation phase of the project. We have a working knowledge of both and are very familiar with the Plant, having made the first functional alterations to it since it's original construction. We have previously looked at the loop, including the connections in the buildings it serves, and in several cases (Buildings 1 main and wings, 3, 4, 5, 8, 10, 15) the building systems with varying levels of scrutiny.

MEI will incorporate this knowledge in evaluating any existing drawings and documentation on the systems. We will also perform an extensive field confirmation of the loop and building systems configurations, documenting the various piping and pumping configurations, and meeting with operations personnel to discuss concerns. All the collected data will be incorporated into a Revit 3 dimensional base model of the chilled water systems, both loop and building interconnection, for us in evaluation and preparation of construction documents. The piping and pump data will then be used in the creation of a flow model to simulate the chilled water loads throughout the campus and to and from the plant. As part of the previous Chiller Plant project MEI created a cooling load model of the campus buildings to estimate the total campus cooling demand. This was used us to formulate the demand load estimates and control methodologies for the plant. In this project, we will refine that flow model to incorporate the additional information we learn in our surveys, including air and chilled water system design capacities, where known, or as we can best determine them.

An integral early piece of this evaluation, a so called "first pass" through the systems, is a thorough review the flow and temperature data currently available on the Ensemble controls system. Based on our current knowledge, we expect to design an early bid package to add flow and temperature meters to the system, initially for the purpose of data collection, and later for use in enhanced chilled water system control. We anticipate situationally using "bolt on" ultrasonic or simple "hot tap" insertion meters, along with strap-on temperature sensors, to permit the work to happen quickly, without the need to drain the systems, allowing data collection to begin ASAP. We further anticipate that a significant number of pump gauges will need to be replaced, so that the hydraulic operating condition of each pump can be determined.

Data collection will also include pump configurations in the system, motor running amps, and pump/ motor label data. This field and controls-based data is imperative to verify the accuracy of the model. We must first understand where the system is operating at this time to determine where it needs to be, both overall for the plant and for each building or building tap. In short, we must understand "where the water is going now" to determine where the water should be going to meet needs without over-pumping, in a more efficient system.

As much as understanding flow in the system is imperative, so is understanding the chilled water temperature dynamics of the system. The data collection will look at temperatures in and out of various system components and buildings to provide more data to the model. Temperature simulation in the model will assist in determining how to best meet the loads while increasing efficiency. The plant is typically running on as 3 – 4 degree "delta T", or difference in inlet and outlet temperature when it should run optimally at 10 – 12 degrees, depending on ambient conditions. In general, this would mean that there is excessive flow in the system, but another factor is likely piping changes that have occurred through the years without a holistic view of the system.

The evaluation process will be labor intensive with considerable field work to accomplish. The result of the effort will be a better understanding of how the system currently operates and ultimately how it should operate. The evaluation begins the process of determining the changes that need to be made, both physically and operationally.

As part of the evaluation we will talk with all stakeholders on the project to determine deficiencies and issues in the current systems; in short, what the operations folks see on a day-to-day basis. We will also identify goals of the upgrades and prioritize these goals. The final step in evaluation is also part of the design process. It is necessary to look at system changes through the eyes of "constructability", in terms of what is actually possible to build, and how the necessary changes can be phased or planned to keep chilled water available where and when it is needed.

Evaluation of the chilled water system must include a holistic look at the controls systems controlling the plant, the loop, and the delivery of water to the buildings, including the so called extraction pumps connected to the loop and the building pumps. While the plant control system was recently upgraded and reprogrammed, it needs review in terms of how it is actually functioning one year later and what the operations staff experience day-to-day. The Ensemble system makes this more possible but we anticipate the need to field verify how the systems are actually responding to control commands. In terms of the aforementioned model, we are working with WVU's School of Engineering to utilize a mechanical engineering post-grad to create a second model, independent of our work, for the purpose of verification of our calculations. While this is not yet set in stone, we are excited at the opportunity to provide an educational benefit as part of the project.

Goal 2.1.2 - Establish Normal Plant Operating Parameters

The establishment of normal operating parameters flows from three general sources of information: the models of the building loads and water flow/temp, the flow/ temp data collected both early and later in the project, and the actual loads determined for each building, which will be a building automation system function. As part of the evaluation, the different chilled pumping configurations in each building need to be understood. The original HF Lenz chilled water system design treated the loop as a chilled water "reservoir" with the loop pumps moving chilled water to each building and returning warmer water to the plant. The chilled water plant loop pumps were only intended for this purpose, moving the water to and from the plant, as a “primary/secondary de-coupled system”. Based on our previous experience and observations, the pumping in individual buildings have been altered as various projects have occurred such that a variety of methodologies are in use with the result that the plant is being asked to do things that were never intended. One such example is the addition of multiple chilled water heat exchangers in Building 3, which in effect created a separate system where one was likely not needed.

The first step in establishing normal operating parameters is determining the system pumping configuration which best serves the campus and align all buildings to use that configuration. It is likely that piping and pumping changes will be required to do so. The flow and temperature models, compared and adjusted to align with the reality in the field, become the prediction method to evaluate operating parameters and their effects on the systems. Historical and real time data collection and trending of both flow and temperature allowing BTU calculations are then compared to the load model predictions at different operating conditions.

Once the parameters are evaluated for their impact, recommended operational methodologies and parameters, including the best use of the free cooling systems, can be determined and established. The real time controls data can be used to calculate loads at building and tap locations across the campus, in tons of cooling, to give the operators a real time understanding of the loads and where and when they occur throughout the campus. This data can also be incorporated into the chiller management system to better predict load changes and the hardware needed to meet them.

The operational parameters will be in written form (a handbook and possibly a help section in the controls system) and are anticipated to be a situational set of recommendations based on events – normal, followed by scenarios: “if this happens, use parameters x,y,z”. Incorporating pre-planned, and most importantly pre-discussed load shed parameters into the handbook, whether routine or emergency, would provide clear direction when those situations arise. While the design team can develop the parameters, input from the operations folks would be critical to finalizing such a document. MEI would assist GSD in classroom and real world training/ rehearsal of personnel on such parameters and procedures.

The initial design of the electrical load demand reduction system with the 2 – 1MVA generators employed a use strategy based on the information available at the time. A similar strategy was used for the chilled water economizer system. The enhancement of the chilled water system, and the data collected on real time loads, will allow the already well functioning system to be further optimized ensuring that the demand limiting is used when necessary but not excessively. The enhanced data collection will also permit the optimization of the demand factor contract for savings, which we see to be an iterative process.

Goal 2.1.3 – Evaluate the Condition of the Distribution Piping

MEI, having evaluated several potential team members, has teamed with CorrView of Landing, New Jersey, for the piping evaluation services. CorrView has been in business since 1981 and has performed evaluation services all over the US on piping evaluation. Their firm profile and business experience is included in the Section 1.

The evaluation of piping will include two major parameters, wall thickness and exterior condition. While the request specifically references buried pipe, an important part of the evaluation will be accessible loop piping which is not buried, such as in buildings, vaults, or the chiller plant. The evaluation of unburied piping provides an initial look at the system and allows comparison of the two conditions. This provides a reference insight on the measurements made for buried piping. One of the major concerns for buried piping is the type, quality, and condition of the insulation. The insulation outer jackets, or wrap is part of the protection system. If it was installed improperly, or degraded, the pipe exterior may have also degraded. CoorView uses ultrasonic methods to evaluate the piping condition but to do so must have direct access to the pipe. It will be necessary to remove insulation on both interior and buried pipe (after excavation) to perform the testing. We anticipate excavating the piping in several locations, likely 4 – 6, for testing. We would excavate a sufficient length of piping at each site to ensure a joint can be evaluated. Depending on what is seen, additional weld testing might be required and a recommendation for such testing, and by whom, would be made at that time. With ultrasonic testing the loop can remain in service while the tests are performed, a significant operational benefit. A sample chilled water piping report, and a published article by Bill Duncan, President of Corrview, is included in the Appendix.

CoorView will utilize the data to determine corrosion rates and percentages of allowable loss, which are critical to making and informed decisions on the piping condition. While CoorView will be performing the evaluation MEI will be on-site and remain directly involved in the evaluation process, including making final recommendations to GSD. If it is determined the piping is to be replaced, MEI would look closely at the piping configuration within the context of the project goals and make recommendations for changes to be made to enhance the system performance.

<u>Goal 2.1.4 – Additional Central Plant Efficiency Enhancements</u>

While MEI has a working history of the plant, this is an area where we also envision taking a fresh look and dropping any preconceived notions. Based on our previous experience, we believe part of the aforementioned 3 – 4 degree delta T concern may well be due to a blending condition within the plant and or the system. As part of the initial flow measurement process, we also envision adding flow meters within the plant, with the goal once again on understanding "where the water is going" within the plant. Once that data is collected, a detailed analysis will reveal any piping or pumping changes that may be advantageous. MEI anticipates that additional automated valves on the chilled water system would be necessary and advantageous. We have asked Dr. Ken Means, retired WVU faculty, to assist in this evaluation and act as a highly experienced and knowledgeable resource throughout the project. Ken performed a similar role on the previous chiller plant projects. MEI will revisit the plant and it's components as part of our evaluation to turn over new opportunities, previously not considered. MEI will research other options in plant equipment configuration for methods to increase efficiency, evaluate cost versus benefit of those methods, and make recommendations for review by GSD. Some initial items includes, cooling tower flow optimization by pump and automated flow (valve) control, tower shutters to optimize winter performance and minimize basin heating, pump performance efficiency evaluation, and individual building pump control impact on the chiller plant.

MEI will review the redundancy of the plant and it's systems in regards to it being critical infrastructure for continuity of government. Single source failure points, such as the 12.4 KV to 4,160 step-down transformers will be evaluated for condition, reliability, and impact on operations, other items such as water supply for cooling towers and the loop will be evaluated. An air cooled chiller component for the plant is an item of consideration. The use of the demand shedding generator powered chillers for complete “off the grid, no utility power” will be evaluated and recommendations made to formalize and harden this capability. MEI can assist GSD with contingency plans. A chilled water system manual operations handbook can be developed with a “black start” option for a time when all power is lost. Any such procedures could be field tested at time of low demand to ensure their accuracy.

One item we have observed, both in the plant and in the loop/ building chilled systems, is a lack of isolation valves in many locations or valves in poor repair. The ability to isolate parts of the system, including the plant from the loop system and vice-versa is critical to maintenance and emergency operations and restoration. As part of the evaluation, we would review the location, condition, and types of isolation valves, and make recommendations for replacement or addition.

Goal 2.2 – Phased Construction Approach

MEI’s understands that chilled water is a year around, critical need for the Campus. Due to both varying people loads and data operations which require cooling year-around. In short, the campus needs chilled water with little exception to remain in operation. This creates a reality of design in which the chiller plant or the loop can be easily shut down for much more than 12 hours, even in winter. Maintaining the chilled water where needed, by providing alternate piping or taps, temporary chillers, will likely have to be factored into the work. MEI has performed many projects using such phased approaches on chiller projects, including GSD projects such as the Building 54 temporary Chiller, Chiller Plant Project, Building 25, and more generally, the ongoing Elevators Project.

We envision the project having more than one phase of bidding and construction documents which will be determined as the evaluation progresses. We anticipate a minimum of an “early package” for the aforementioned metering, a package for the loop/ building interconnects, and one for the chiller plant. We see a second interconnect package as a possibility depending on the scope and design time required to detailed the work.

A phased approach requires a detailed and extensive review of the existing facility, the systems to be affected, their effect on other facilities, and operations, to determine any limitations this may cause to the phased approach. MEI will review the existing conditions and proposed work to be performed to determine an initial project phasing schedule, in deep coordination with GSD. MEI will coordinate the scope and phasing of the project with GSD to give GSD an understanding of the project schedule. A phased project will require coordination between the contractor and GSD regarding outages, the installation or modification of equipment, and the impact on operations. MEI will work with GSD to determine the best methods and time/ season for accomplishing the work and the delineation of responsibility for phased work including time limits for outages, where applicable. MEI will incorporate the phasing timing and requirements into the project documents by clearly indicating on the drawings and in the specifications the number of phases, which areas and activities are in each phase, and milestones in the construction schedule for each phase. This creates a so-called “order of battle” for contractor implementation of the project. Projects in which MEI recently used a phased approach include:

- GSD Chiller Plant Renovations
- GSD Elevator Modernizations Ph 1 and Ph2

- Building 25 HVAC Piping Replacement
- Pipestem State Park McKeever Lodge Piping Replacement
- WVDA Ripley Warehouse Electrical Upgrades
- WVANG Bridgeport FWAATS Restroom Renovations

Goal 2.3 – Design Standards & Criteria

MEI has completed many projects serving as the prime consultant. As such, this role requires us to operate within the procedures and requirements of the owner. We have served in this role many times for various state entities including the WV Division of Natural Resources, WV Army National Guard, and WV General Services Division.

MEI will begin to consider and incorporate design standards and applicable codes into the project during the evaluation phase. In the field, MEI will review and document observed safety and code related concerns that might be affected, or need to be addressed, as part of the project scope. Once the evaluations and models are accomplished, and MEI grasps the intent and construction scope, MEI will meet with GSD. The meeting will involve all stakeholders to gain an understanding of the intended project outcomes. A review of all applicable codes and guidelines related to the project including ASHRAE, building codes including mechanical, electrical, plumbing, piping, and NFPA, and construction standards such as ASME, ASTM, ANSI, NEMA, etc. is conducted in initial design and approach to a solution. MEI will discuss items which will affect the renovation including GSD requirements related to construction, call them the “Owner’s standards”, for incorporation into the design. Any GSD related insurance concerns and historical context will be reviewed at this time. As MEI has worked on many projects falling under BRIM inspection, we understand the need for compliance with the WV codes in place at the time of design. MEI has been asked for responses to BRIM comments on projects, sometimes years after the project was completed, and has always done so as a courtesy to our clients.

Miller Engineering's staff has backgrounds in construction, maintenance, and operations which provide a unique perspective as we do not just think "Will it work?" but also consider "How will it be installed?" and "How well can it be maintained to work as intended?" By early consideration of such factors, MEI generally avoids concerns with standards and constructability later in the project. We begin to think in terms of bidding documents in schematic design. We find this minimizes translation error between submissions. The initial schematic design will be the basis of the 35% documents. MEI will provide cost estimates using real material quotes and take-offs to convey projected costs to GSD, which in schematic are generally order of magnitude.

MEI will take input from GSD based upon review of the 35% design documents and proceed. MEI will not wait until the next progress set to speak with the stakeholders if questions arise, we will ask them immediately. Our philosophy is that the sooner issues are brought forward and addressed, the less they cost the project in time and money. The estimate will also be updated regularly as MEI treats the estimate as a "living document." Any changes or inputs from GSD, as well as other changes made during proceeding with design development, will be reflected in the estimate. MEI believes in giving GSD the information necessary, including budgetary effects, to make informed decisions regarding the design. The follow-on progress sets will reflect the outcomes of the formal and informal discussions with the GSDs.

The construction documents will be completed using both the results of the progress set reviews and internal peer review. MEI understands that while working on a project, engineers and designers can get "tunnel vision", meaning they see what they want to see reflected in the documents. All drawings and specifications issued by Miller Engineering go through a three step peer review internally to ensure the intent of the document is clearly transmitted. Project specifications will reference applicable codes and standards to ensure the proper quality and best industry practices. MEI will work with GSD to ensure the bidding and procurement procedures are included in the project documents. The final 100% construction document set will be issued to the GSD for bidding, along with our best estimate of probable cost. These include the appropriate bid forms, AIA General Conditions, WV Supplementary Conditions, State Safety Protocols, and various other AIA documents required by WV GSD and Purchasing.

During bidding, Miller Engineering will assist GSD to successfully procure bids for the upgrades. MEI will be present during the pre-bid meeting to discuss the technical scope of work for the project. Any technical questions from contractors or vendors to GSD during bidding will be answered by MEI. MEI will provide addendum documents as needed. MEI will also assist in reviewing bids and making recommendations to GSD. We have completed many projects through WV State Purchasing, and understand the requirements to successfully bid a project with the state of West Virginia.

After bids are received and the contract awarded, MEI is not a firm that disappears until the final punch list. MEI will provide thorough construction administration (CA) services as agreed upon with the GSD. We believe it is our obligation to enforce the contract, including plans and specifications and all of the codes and standards found therein, to GSD’s interest. We will be present for a construction kick-off meeting to make sure the project gets off on the right foot. MEI believes in being present at construction progress meetings and making informal site visits to keep the project on track. Our background in construction and operations allows us to understand the sequencing of construction in the field to better aid the contractors when questions arise. One of MEI's main beliefs is that any requests for information (RFIs) submitted by the contractor should be reviewed and answered within one business day if possible. This is because we understand that delays in RFI responses can lead to additional costs and construction days. If necessary, we will provide an informal answer and follow up with the formal response to keep the project rolling.

During progress meetings and site visits, any issues discovered by MEI will be relayed to GSD and contractor immediately to prevent delays. Another company standard is for our staff to be present for testing and balancing (TAB), equipment start-up, and GSD training. While these events occur at the very end of the project, they are critical to ensure the new systems operate as designed. MEI will be on hand for these activities to quickly answer any questions and confirm these items are performed properly in accordance with the construction documents. We anticipate that the nature of this project will require initial and follow-on training for GSD personnel over the course of at least the first year to ensure the changes are operated and maintained properly.

Goal 2.4 – Technology & Energy Conservation

MEI has witnessed a great deal of change in terms of technology over the last 20 years, the incorporation of cheaper digital technology into mechanical systems has changed the HVAC industry and provided methods for increasing energy efficiency. It has also created a need for us to keep current on what new technologies are up and coming. We are always researching new technologies, seeking new industry sources and equipment for incorporation into our design, while also evaluating them for reliability. We have recently been using “self-sensing pumps” on projects such as the WVDNR Cacapon and Blackwater Falls Lodge renovation chilled water systems replacements and the Camp Dawson Op Center HVAC Renovations. These pumps are variable speed pumps with an integral drive and, once set up, they adjust to the load automatically. They do so without any controls or pressure gauges or inputs, based solely on the operating conditions they sense through the drive/ motor feedback. These have proven to be very reliable and have significantly reduced pumping energy on the projects, which was demonstrated during the project testing and balancing.

Another technology we have utilized on recent projects including the Chiller Plant Renovation is a product called an AEGIS ring. Research over the last few years has shown a significant rate of bearing failure in pumps and AHUs with variable frequency drives. Under the right conditions, the drive will induce voltage onto the motor shaft and damage the bearings. In some cases the currents have cut a blower shaft off perfectly clean. The Aegis shaft grounding rings work by diverting the damaging voltages away from the bearings, sending it to ground through the motor frame. We have made these a specification standard for all VFD motors.

MEI will design the project to meet ASHRAE62.1-2013 and the 2018 IECC recently adopted by the state legislature, as applicable, and operability and maintainability which are crucial to energy efficiency. We are committed to optimizing energy efficiency whenever it if feasible to do so. Another important part of energy conservation is verification over time. We would anticipate developing recommendations for documented benchmarking of equipment, initially to verify initial performance, and over time to ensure the equipment is continuing to operate as anticipated. There is also a discussion to be had concerning commissioning of systems and applicability to the project.

Goals Five – 2.5 Quality Control Program

During construction, we believe on a “boots on the ground approach” making formal and informal site visits, both planned and unannounced, to review work progress and quality. Both Craig and Travis’ years of experience in construction and maintenance activities permit them to quickly identify code, standard, or quality concerns in the field. Thorough review of submittals against the specifications by staff, and additional review, also by Travis or Craig, minimizes submittal deviations from the specifications. We offer our change order rate over the last 15 years, significantly less than 0.1%, as demonstration of our quality control processes during design and construction.

After construction, only successful operation of modernizations and enhancements over time leads to the anticipated energy savings, so maintenance and troubleshooting become critical. MEI has created maintenance programs, schedules, and procedures for clients in the past. At Canaan Valley Lodge, MEI reviewed all of the lodge’s MEP systems, researched their O&M documentation, and created a maintenance schedule with procedural pointers. For all of the major MEP systems, the Owner was provided with a check list, a detailed description/ instruction of the maintenance procedure and the intervals to perform said maintenance. This was done on systems designed by other firms, so MEI started from ground zero. The procedures are still being used at this time and have reduced system failures and problems. A sample of one type of check list is included in the Appendix.

We plan to use a similar approach for this project. By reviewing the maintenance requirements and turning the information often buried in O&M manuals into a readily available, understandable, and documentable format, the likelihood of proper maintenance increases. Our time on site during construction helps to ensure we address the realities of such maintenance

As part of project close-out, MEI will require the contractor to demonstrate proper system operations to prior to any training being scheduled. This is to avoid the distraction of "startup during training"; which can occur with a generic project specification. Operational demonstration prior to training is something MEI requires on all projects in all disciplines, especially building and lighting control systems.

Training of the maintenance staff is critical to operation of these systems. Periodic re-training during the warranty period seems imperative and we plan to incorporate those needs into the project bid documents. The contractor will also be required to train GSD's staff on the operation and maintenance of these systems. The training requirements will be detailed in the specification to go beyond the normal orientation type training to include problem solving and troubleshooting. Training can be required over multiple sessions to permit GSD's personnel time to review the training on the actual systems and ask follow on questions at the next training session. MEI will require this training to be recorded with copies delivered to GSD. MEI also extensively reviews all as-built drawings and O&M manuals for completeness. The contractor will be required to return at the 11^{th} month of the warranty period to test and verify the systems are still operating as intended. One option we have used in the past is an extended warranty on such systems with training requirements beyond one year, giving the maintenance personnel even more opportunity to become proficient with the systems.

As part of quality control, we anticipate revisiting the water treatment program, both chilled and tower water. A good first step was taken in the Chiller Plant Renovation with in installation of an aggressive side stream filters; it is likely more needs done on this front. The importance of water treatment is generally known, it like many other things, is changing with time and technology. MEI and CorrView will review the existing program, make recommendations, and assist in setting up and procuring such a program, including personnel training.

TAB 3 –STAFF QUALIFICATIONS

B. Craig Miller, PE

Craig founded Miller Engineering in 2003, and serves as President and Principal Engineer. He has more than 25 years of experience in design, specification, operations and project management. Since forming Miller Engineering, he has implemented hundreds of project with an emphasis on facility renovation. His broad experience runs the gambit of facility and client types. During his employment with WVU, Craig was directly involved with approximately $130 million in new capital construction. His experience with a wide range of projects including HVAC, electrical, plumbing, infrastructure upgrades, building automation, energy efficiency and maintenance/renovation, among others, allows him to serve in multiple capacities within a given project. Craig will serve as the “LEAD Reviewer” for Miller Engineering as the main communication interface between the Owner, the Owner’s design team, and if third party CA occurs, contractors.

Project Role: Relationship Manager – Primary Point of Contact

- *Engineer in Responsible Charge*
- *Design and Project Management of Mechanical, Electrical, Plumbing Projects*
- *Concept and Construction Design*
- *Business Operations and Financial Management Oversight*
- *Quality Assurance and Control*

Professional Project Highlights

- WV GSD Building 3,11,54, 86 IAQ Assessment
- WV GSD Building 25 Humidity and Ventilation Assessment
- WVU Life Sciences Building and Student Recreation Center – Owner’s Engineer
- WV GSD Various Elevator Modernizations
- WV Building 25 HVAC Piping
- Advanced Surgical Hospital
- WV Building 36 HVAC
- Capitol Complex Chiller Plant Modifications
- Canaan Lodge Addition Third Party CA

Professional History

2003- Present	Miller Engineering, Inc.	President, Relationship Manager, Engineer of Record
2002-2003	Casto Technical Services	Existing Building Services Staff Engineer
2001-2002	Uniontown Hospital	Supervisor of Engineering
1995-2001	West Virginia University	Staff Engineer
1990-1995	BOPARC	Caretaker – Krepps Park
1983-1988	University of Charleston	Electrician/HVAC Mechanic

Education

1995	West Virginia University	BS- Mechanical Engineering
1988	University of Charleston	BA- Mass Communications

Licenses and Certifications

- Professional Engineer (West Virginia, Pennsylvania, Maryland)
- Licensed Master Plumber
- LEED-AP Certified

Travis Taylor, PE

Experience in project management facilitates Travis's ability to create and design constructible projects. Prior to joining the Miller Engineering team he was directly responsible for managing $10 million in electrical construction budgets. His experiences encompass both new construction and renovation. Travis maintains professional competencies by attending seminars and continuing education classes. Theseinclude local ASHRAE classes in addition to classes on electrical systems, and also steam systems through Shippenburg Pump Company. As lead engineer he provides HVAC, mechanical, plumbing, and electrical design solutions and services for our clients. In addition, he is part of our team's complete assessment process in both planning and MEP design through construction administration. Travis will backup Craig as review on this project and will direct the staff as required to support the review effort.

Project Role: Lead MEP Engineer

- *Design of Mechanical, Electrical, and Plumbing Systems*
- *Building Information Modeling - Revit*
- *Constructible Materials Evaluation*
- *Site Evaluation and Mechanical System Review*
- *Submittal and RFP Review*
- *RFI Coordination, Review, and Response*
- *Construction Observation*

Professional Project Highlights

- WV Building 25 (HVAC Piping, 6th Floor & Façade, HVAC)
- Cacapon Lodge Additions & Renovations
- WV State Building 36 HVAC Upgrades
- Alderson Broaddus Withers Brandon Hall HVAC
- Capitol Complex Chiller Plant Modifications
- South Middle School HVAC Renovations
- WV Veterans Memorial
- Pipestem Lodge McKeever Lodge HVAC Piping Replacement

Professional History

2011-Present	Miller Engineering, Inc.	Staff Engineer
2006-2011	Tri-County Electric, Co.	Project Manager
2006-2006	Schlumberger	Field Engineer Trainee - MWD

Education

2006 West Virginia University, BS – Mechanical Engineering

Licenses and Certifications

- Professional Engineer – West Virginia, Maryland
- OSHA 10-hour Course: Construction Safety & Health

Staff – Qualifications and Experience

Jack Jamison

Jack brings 20 years as an electrical/building inspector and over 25 years of experience in the commercial electrical construction industry. His knowledge and experience are valuable resources to Miller’s complete assessment process.

Project Role: Master Code Official

- *FacilityReview,CodeResearch,FieldObservations,IssueResolutions,andProjectEvaluation*

Professional History

2010- Present	Miller Engineering, Inc.	Code and Construction Specialist
1999-2010	Megco Inspections	Chief Inspector
1972-1998	Jamison Electrical Construction	Master Electrician

Education

1971 Fairmont State College, BS-EngineeringTechnology-Electronics

Licenses and Certifications

- Master Code Professional, IAEI Master Electrical Inspector, Class C Electrical Inspector – WV, PA, MD, &OH
- ICCCommercialBuilding,BuildingPlans,CommercialPlumbing,ResidentialEnergy,andAccessibility Inspector/Examiner
- WV Master ElectriciansLicense
- NCPCCI-2B, 2C, 4B, 4C: Electrical & Mechanical General/PlanReview
- OSHA 30 Hour Course: GeneralIndustry
- NFPA Code Making Panel 14 – NEC 2014Edition

Tyler Trump

Tyler joined Miller Engineering in August 2022. A recent graduate of West Virginia University, he has been eager to learn the means and methods of MEP consulting. Tyler assists the MEP design team with design calculations and is rapidly learning design software such as Autodesk REVIT and Hourly Analysis Program by Carrier. He is also learning construction administrations along with building, electrical, and plumbing codes and standards. Tyler is currently preparing to take the Fundamentals of Engineering Exam.

Project Role: Junior Engineer

- *Design Calculations*
- *Drafting of MEP Systems*
- *Assist with Construction Administration*

Professional Project Highlights

- Cass Scenic Railroad State Park Campground
- Lost River Campground
- Mountain Line Transit Authority Office Renovation
- Ronald McDonald House Addition & Renovations

Professional History

2022- Present	Miller Engineering, Inc.	MEP Designer

Education

2022 West Virginia University, BS - Mechanical Engineering

Licenses and Certifications

What our satisfied customers have to say…

*"*Hard working, do-whatever-it-takes, diligent team that provides excellent customer service is what you can expect from Miller Engineering."

--Chris Halterman, Dominion Post, Morgantown

"As a design/build team, working with Miller Engineering, our project involving a private surgical hospital together was a success – completed ahead of schedule and on budget. Miller worked with us throughout the project to consult, engineer and inspect the mechanical systems. Craig Miller, PE and his staff are working with us again, and are very important members of our design/build team. I highly recommend their services.

--Richard J. Briggs

Barrow Koslosky, AIA *Chief of Planning, Engineering & Maintenance* *WV Division of Natural Resources* *State Parks Section* *324 4th Avenue* *South Charleston, WV25303* ***(304) 558-2764*** barrow.a.koslosky@wv.gov	**Paul Braham** Associate Director of Maintenance & Engineering *Mylan Pharmaceuticals* *781 Chestnut Ridge Road* *Morgantown, WV 256505* ***304-288-8659***	**Bill Barry** *Director* *WV General Services Div.* *401 California Ave.* *Building 4, 5th Floor* *Charleston, WV 25305* ***(304) 558-1808*** William.d.barry@wv.gov
Bob Ashcraft *Safety and Ancillary Projects* *Monongalia County Schools* *533 East Brockway Street* *Morgantown, WV 26501* ***(304) 657-4079***	**Dave Parsons** Energy Program Manager *WV General Services* *112 California Avenue* *Building 4, 5th Floor* *Charleston, WV 25305* ***(304) 957-7122*** David.K.Parsons@wv.gov	**Richard J. Briggs** Vice President *Lutz Briggs Schultz & Assoc. Inc.* *239 Country Club Drive* *Ellwood City, PA 16117-5007* ***(724) 651-4406*** lbsa@zoominternet.net

From Jonathan Miller, Mechanical Project Manager, Nitro Mechanical:

"Miller Engineering is not your average engineering company; they work with the owner AND the contractor to solve all issues that arise throughout the project to make the process as fluid as possible"

construction
ECKLES
services, inc.

301 north mercer street
new castle, pa 16101
p 724.652.5507
f 724.652.0751

February 7, 2020

RE: Letter of Reference Miller Engineering

To whom it may concern

I am writing this letter of reference on behalf of Craig Miller, Miller Engineering, Inc., Morgantown, WV. My company, Eckles Construction Services, Inc. has been providing Clerk of the Works services for the Monongalia County Board of Education for the past five years. We have worked on various projects, ranging from additions and renovations to new building construction, during our involvement with the county. Those projects have been designed by different Architectural and Engineering design teams. Most of the projects have also received SBA funding.

It has been our privilege and pleasure to work with Craig and his team on four projects during that time; two of which received partial SBA funding. Mr. Miller is extremely knowledgeable regarding MEP systems and their operation. He is perhaps the most hands on engineer I have encountered in my 27 years of related school construction in both Pennsylvania and West Virginia. More importantly Miller Engineering is very responsive to the contractors needs during the construction process.

I would not hesitate to recommend Miller Engineering as the Design Professional for your project.

Regards,

Kenneth Holsopple

President

PENNINGTON PLUMBING & HEATING INC.
301 George St. Beckley WV 25801 **License WV 001456**

April 17, 2019

To Whom it May Concern,

Re: Miller Engineering Design Firm

Pennington Plumbing & Heating has worked with Miller Engineering on numerous projects throughout the years, ranging in size from several hundred thousand dollars to several million. We have always found their firm to be professional, competent, and helpful.

We have found that they are always available to help on challenging situations on different projects, and their designs have had great success on the projects that we have been involved with. They have the capability to handle MEP designs of any size and are always open to modifications that allow the owner to save time and money while maintaining the highest quality and design intent.

We would have no issue recommending their firm to building owners seeking design and construction administration.

Should you have any questions please do not hesitate to contact me.

Best Regards,

Eric Mahaffey
President.

June 6, 2018

RE: Miller Engineering

To Whom it May Concern,

I have worked on several project with Miller Engineering, over the last few years. Craig Miller and his staff are some of the most detail-oriented engineers I have met. They take extra time, and care, to ensure that their design meets the requirements set forth by the owner and that trades are coordinated properly. Their staff make routine visits to the jobsite to ensure the quality of installation meets their specified standards.

Miller Engineering is also willing to help with value engineering, if required, to meet budgets. However, they are not willing to sacrifice the quality, set forth, in their original design standards. This is an admirable trait in today's engineering world. Many times, value engineering is done without the original designer's review or they may allow substandard products and quality is sacrificed as a result.

In closing, Craig Miller always states that "working with them is different". He's correct. In a world where things are done with little input or involvement by the engineering firm during construction, they stand out as a firm who truly cares. They put thought into their design and the functionality of buildings and the results speak for themselves. Their designs are quality and built to last.

Brian D. Gaudiano

Vice President

MacBRACEY CORPORATION

P.O. Box 558
2155 Park Avenue
Washington, PA 15301

General Construction & Consulting

Phone 724/229-0119
Fax 724/225-1180

To whom it may concern,

As the Vice-President and Lead Project Manager of MacBracey Corporation, a commercial and industrial general contractor located in Washington, PA, I am writing to support and endorse Miller Engineering and their ability to provide construction design services as well as project management.

MacBracey has found Miller Engineering's drawings and specifications to be both thorough and accurate as to the in-field conditions. Any issues that have come about throughout a construction project Miller Engineering is quick to develop a corrective plan and ensured the project doesn't face delays.

I have found Miller Engineering to go above and beyond the industry standard throughout the entire construction process to make sure everything stayed on track. I have spoken with many members of Miller Engineering "after hours" to solve an issue that needed addressed by the following morning. This is a characteristic that you don't see with a lot of design teams.

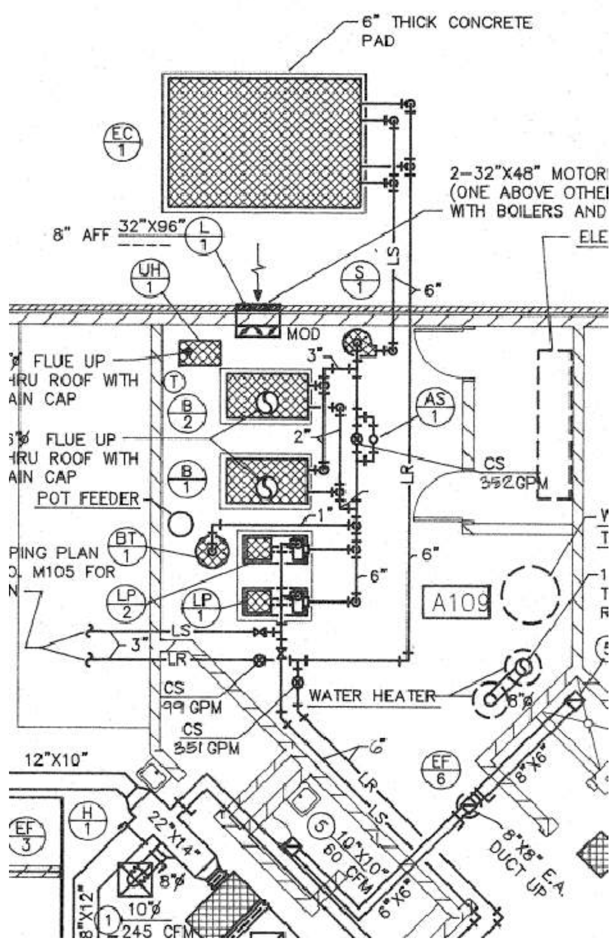
I found the entire Miller Engineering team to be both knowledgeable and professional. We at MacBracey would enjoy the opportunity to work with Miller Engineering again in the future. It is truly refreshing to work with a design team that has a passion for the industry and is willing to work with everyone involved to ensure the project gets done correctly and in a timely manner.

Sincerely,

Patrick Bracey

Patrick Bracey
Vice President,
MacBracey Corporation

TAB 4 – EXPERIENCE



Experience –Electrical & Mechanical

Capital Complex Chiller Plant Evaluation and Modifications

Services Provided:

- Evaluation – Study
- Electrical
- Mechanical
- Plumbing

Project Cost: $7.26 mil
Facility Area: Approx. 7,500 ft^2
Owner: WV GSD

The existing chiller plant serving the WV State Capital Complex is 20 years old. The Owner wishes to reduce energy costs associated with the peak electrical demand metering applied to the plant's electrical service. MEI was retained to evaluate multiple options to reduce electrical demand, and thereby the operating costs. The determined optimal solution is to use large, medium voltage, natural gas generators which could operate select chillers during peak demand to reduce electrical peak demand. A 5kV switchgear will allow the select chillers and their respective pumps to operate under generator load when they are required to come online. A new 2,300 ft^2 building will be constructed to house the new switchgear, pumps, and heat exchangers to allow the chillers to still operate as a plant. The project was completed in May of 2022.

Project Contact:
Dave Parsons
Energy Manager
WV GSD
112 California Ave.
Charleston, WV
304-957-7122

Descriptions of Past Projects Completed – Renovation

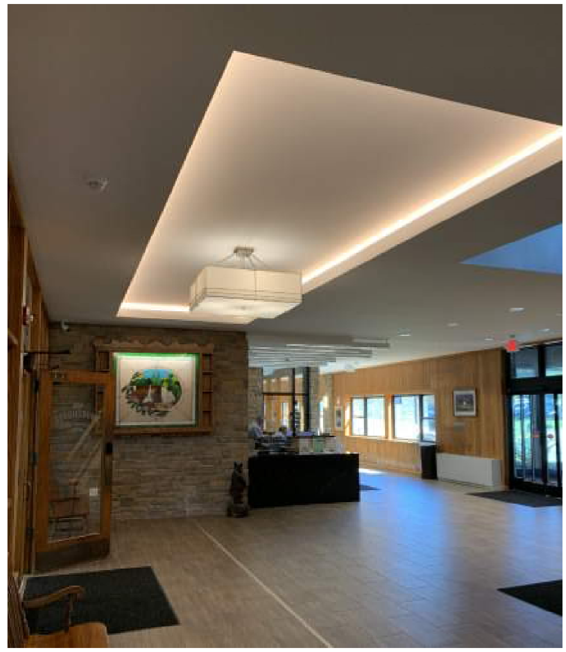
Blackwater Falls State Park Lodge Renovations

Davis, WV

Services Provided:

- General Trades
- Plumbing
- Electrical
- Mechanical
- Pool

Const. Cost: $4.6 Mil
Facility Area: 44,000 ft^2
Owner: West Virginia Division of Natural Resources



Project Contact:
Barrow Koslosky, AIA – Chief of PEM
WV DNR
Phone: (304) 558-2764

MEI was part of a design team with Paradigm Architecture to design the interior renovations to the lodge at Blackwater Falls State Park. All 54 lodge guestrooms were completely renovated with new finish, HVAC, and bathroom upgrades. Four of the guestrooms were modified to meet modern ADA guidelines. The lobbies, reception area, and dining rooms were upgraded with new HVAC, lighting, and finishes. The original finned tube radiant was replaced with new 4 pipe fan coil units and were tied into the boilers which were recently replaced by a previous MEI project. A new chiller was installed with pumps and chilled water piping to the fan coil units. The guest rooms HVAC systems are fan coil units with ventilation served by make-up air units. Energy recovery ventilators pre-condition outside air to make the make-up air units operate more efficiently. The lodge was re-opened in January 2022.

Project Experience: HVAC Upgrade

West Virginia State Building 25

Parkersburg, WV

Services Provided:

- Mechanical Piping
- Electric
- Construction Administration

Estimated Budget: $843k
Facility Area: 58,500 ft^2
Owner: State of West Virginia – General Services Division

The PVC piping system at Building 25 had a history of leaking, along with smaller piping sagging over time and breaking, prompting the owner to replace the entire system. The building was a logistic challenge to design due to offset multi-level mezzanines, resulting in low deck-to-deck heights in the lower levels. A new, rolled-groove piping system was installed, including a new cooling tower and supporting structure, and connected to the original boilers. To eliminate the problems associated with manganese, which forms solids and clogs piping, the system was converted from water to propylene glycol with the flow rates adjusted to accommodate the change. The water source heat pumps which serve the building were flushed and cleaned to prevent contamination of the new water. MEI designed a phased approach to accomplish the piping, which was adjusted in consultation with the owner and contractor during construction to minimize the impact on the building occupants, who remained in the building during the entire construction period. MEI worked on an almost daily basis with the contractor to accomplish the re-piping of the building, providing support and real-time answers to questions and to work around challenges.

Project Contact:
David Parsons, Operations and Maintenance Manager
State Capitol, Room E-119
(304) 957-7122

Project Experience: HVAC Upgrade

West Virginia State Building 36 (1 Davis Sq.)

Charleston, WV

Services Provided:

- HVAC System Replacement
- Mechanical Piping
- Electric
- Construction Administration

Estimated Budget: $2.1M
Facility Area: 58,400 ft^2
Owner: State of West Virginia – General Services Division

The 30-plus year old chiller serving Building 36 failed in the spring of 2016. MEI was retained to design the installation of a temporary rental chiller, which remains in service at this time. MEI was then retained to design a full HVAC retrofit to the building due to the condition of the air handlers, ductwork, VAV boxes, and associated systems. The building presented unique challenges as it was originally two buildings in which the common space was later in filled to create one building. The deck to deck heights in some areas are very limited, resulting in the need for accurate evaluation, design, and detailing in the construction documents. MEI designed a phased approach to accomplish the project. The phasing was developed directly with the owner to minimize the impact on the building occupants; who had to relocate to swing space phase by phase. Instead of just replacing the existing system in-kind, MEI designed a system utilizing three rooftop units ducted vertically through the building, which eliminates the sole source failures that have plagued the system for several years. The project is ready for bid at this time.

Project Contact:
David Parsons, Operations and Maintenance Manager
State Capitol, Room E-119
(304) 957-7122

Descriptions of Past Projects Completed – HVAC, Electric

Withers Brandon Hall

Philippi, WV

Services Provided:

- Electrical
- HVAC

MEP Budget: $700k
Facility Area: 31,800 ft^2
Owner: Alderson Broaddus University
Status: In Construction

As part of renovations to Withers Brandon Hall at Alderson Broaddus University, MEI was brought in to evaluate and design upgrades to the HVAC system. The existing chiller and piping insulation had failed. The existing system was a two-pipe system with chiller and boilers serving fan coil units. MEI proposed to re-use the piping and replace the fan coil units with water source heat pumps (WSHP). This allows the existing piping to be re-used and piping insulation would not have to be replaced. The chiller will be replaced with a fluid cooler located outside the building. The three non-condensing boilers will be replaced with a much more efficient modulating condensing "double stack" boiler. The ventilation units are located in the unconditioned attic space and are difficult to perform maintenance on. New ducted heat pumps tied to energy recovery ventilators will tie into the existing fresh air duct to provide ventilation and relief air. The design limits the amount of modifications outside of the mechanical rooms which will aid with the compressed construction schedule. The project was completed in October 2019.

Project Contact:
David Snider, AIA
Omni Associates, Inc
(304) 367-1417

Project Experience: Elevators

WV GSD Various Elevator Modernizations

Charleston, WV

Services Provided:

- Elevator Evaluation
- Mechanical
- Electrical
- Plumbing
- Fire Alarm
- Fire Protection
- Construction Management

Estimated Budget: $20M
Facility Area: N/A
Owner: WV GSD

MEI and Richard Kennedy and Associates were retained to evaluate 31 existing elevator systems and design modernizations of each in a three phase project approach. The scope of service includes modernizing the machine rooms and brining the systems into compliance with no or a few variances as possible. The team prepared a detailed report with discussions, estimates, recommendations, executive summary, and an elevator system “primer” to assist readers in more thoroughly comprehending the report. Phase I Involved 7 elevators at the WV Capitol Building, 2 elevators at WV Building 7, and 2 elevators at WV Building 25. The work related to the passenger elevator cars, doors, and landings will be in accordance to guidance from the WV State Historical Preservation Office. Phases I & II are currently in construction.

Project Contact:
Pat O’Neill
Project Manager
WV General Services Division
112 California Ave
Charleston, WV
304-957-7133
Patrick.s.oneill@wv.gov

MILLER ENGINEERING, INC.

TAB 5 – PROJECT FORMS

Department of Administration
Purchasing Division
2019 Washington Street East
Post Office Box 50130
Charleston, WV 25305-0130

State of West Virginia
Centralized Expression of Interest
Architect/Engr

Proc Folder: 1165807			**Reason for Modification:**
Doc Description: Campus Chill Water Loop / Plant Evaluation and Enhancements			
Proc Type: Central Contract - Fixed Amt			
Date Issued	**Solicitation Closes**	**Solicitation No**	**Version**
2023-01-30	2023-02-14 13:30	CEOI 0211 GSD2300000007	1

BID RECEIVING LOCATION

BID CLERK
DEPARTMENT OF ADMINISTRATION
PURCHASING DIVISION
2019 WASHINGTON ST E
CHARLESTON WV 25305
US

VENDOR

Vendor Customer Code:

Vendor Name :

Address :

Street :

City :

State : **Country :** **Zip :**

Principal Contact :

Vendor Contact Phone: **Extension:**

FOR INFORMATION CONTACT THE BUYER
Melissa Pettrey
(304) 558-0094
melissa.k.pettrey@wv.gov

Vendor Signature X **FEIN#** -1386 **DATE** 14 Feb 2023

All offers subject to all terms and conditions contained in this solicitation

DESIGNATED CONTACT: Vendor appoints the individual identified in this Section as the Contract Administrator and the initial point of contact for matters relating to this Contract.

(Printed Name and Title) B. Craig Miller, PE - President

(Address) 54 West Run Road Morgantown, WV 26508

(Phone Number) / (Fax Number) (304) 291-22358

(Email address) cmiller@millereng.net

CERTIFICATION AND SIGNATURE: By signing below, or submitting documentation through *wv*OASIS, I certify that: I have reviewed this Solicitation/Contract in its entirety; that I understand the requirements, terms and conditions, and other information contained herein; that this bid, offer or proposal constitutes an offer to the State that cannot be unilaterally withdrawn; that the product or service proposed meets the mandatory requirements contained in the Solicitation/Contract for that product or service, unless otherwise stated herein; that the Vendor accepts the terms and conditions contained in the Solicitation, unless otherwise stated herein; that I am submitting this bid, offer or proposal for review and consideration; that this bid or offer was made without prior understanding, agreement, or connection with any entity submitting a bid or offer for the same material, supplies, equipment or services; that this bid or offer is in all respects fair and without collusion or fraud; that this Contract is accepted or entered into without any prior understanding, agreement, or connection to any other entity that could be considered a violation of law; that I am authorized by the Vendor to execute and submit this bid, offer, or proposal, or any documents related thereto on Vendor's behalf; that I am authorized to bind the vendor in a contractual relationship; and that to the best of my knowledge, the vendor has properly registered with any State agency that may require registration.

By signing below, I further certify that I understand this Contract is subject to the provisions of West Virginia Code § 5A-3-62, which automatically voids certain contract clauses that violate State law; and that pursuant to W. Va. Code 5A-3-63, the entity entering into this contract is prohibited from engaging in a boycott against Israel.

Miller Engineering, Inc.

(Company)

(Signature of Authorized Representative)

B. Craig Miller, PE - President

(Printed Name and Title of Authorized Representative) (Date)

(304) 291-2234

(Phone Number) (Fax Number)

cmiller@millereng.net

(Email Address)

ADDENDUM ACKNOWLEDGEMENT FORM
SOLICITATION NO.: CEOI GSD2300000007

Instructions: Please acknowledge receipt of all addenda issued with this solicitation by completing this addendum acknowledgment form. Check the box next to each addendum received and sign below. Failure to acknowledge addenda may result in bid disqualification.

Acknowledgment: I hereby acknowledge receipt of the following addenda and have made the necessary revisions to my proposal, plans and/or specification, etc.

Addendum Numbers Received:
(Check the box next to each addendum received)

☑ Addendum No. 1	☐ Addendum No. 6
☐ Addendum No. 2	☐ Addendum No. 7
☐ Addendum No. 3	☐ Addendum No. 8
☐ Addendum No. 4	☐ Addendum No. 9
☐ Addendum No. 5	☐ Addendum No. 10

I understand that failure to confirm the receipt of addenda may be cause for rejection of this bid. I further understand that any verbal representation made or assumed to be made during any oral discussion held between Vendor's representatives and any state personnel is not binding. Only the information issued in writing and added to the specifications by an official addendum is binding.

Miller Engineering, Inc.
Company

Authorized Signature

14 Feb 2023
Date

NOTE: This addendum acknowledgement should be submitted with the bid to expedite document processing.

TAB 6 – APPENDIX

CorrView International, LLC
P.O. Box 8513, Landing, NJ 07850
Tel: 973.770.7764 * Fax: 973.770.6576
www.corrview.com
info@corrview.com

ULTRASOUND

Pipe Testing and Analysis Report

prepared for

Mechanical Inc.

submitted to the attention of

Mr. Bill

Project Superintendent

Test Site: Service Tunnel

Chill Water and Hot Water Heating

Report Submitted: January 23, 2017

- SECTION ONE -

Executive Summary

On December 30, 2016, CorrView International, LLC performed a series of ultrasonic pipe wall thickness tests upon 59 different locations within the B service tunnel at xxxxxxxxxxxxxxxxxxxx. The survey was initiated by Mr. Bill xxxxxx, Project Superintendent for xxxxxx Mechanical Inc., in order to identify the condition and remaining service life of the chill water and hot water heating piping.

This investigation has produced generally good results. For the chill water piping, which was suspected as having the greatest vulnerability due to obvious outer surface rusting, testing identified still high average wall thickness capable of providing very extended service life. In areas where there was no surface rust, ultrasonic testing of the chill water pipe identified low corrosion loss and very high wall thickness often near new schedule 40 specifications. Removing the surface rust in areas most heavily impacted revealed random surface pitting to near 0.035 in. at most examples, with deepest pitting measured at near 0.060 in. This surface deterioration has had only minimal impact to the larger diameter chill water pipe, but now requires a rehabilitation of the pipe in order to eliminate it future threat.

For the hot water heating pipe, testing identified noticeably higher corrosion activity overall. We also identified a dramatic difference between conditions at the supply and return side piping, with noticeably higher deterioration occurring to the supply side. Such higher deterioration can be explained for this older piping system due to rust particulates settling within the supply line due to potentially lower than adequate flow velocity. As rust particulates accumulate and settle over time, they dramatically reduce the effectiveness of any anti-corrosion chemical treatment by limiting its contact with the underlying bare steel.

> **While such deterioration has had a moderate impact against the larger diameter main lines, smaller take-off piping has now been reduced to minimum acceptable limits in some examples. For that reason, we are recommending the replacement of all take-off piping from the hot water heating mains.**

For both the chill water and hot water heating systems we are recommending the installation of some form of filtration in order to gradually remove existing rust deposits. Effective filtration operation requires the addition of chemical rust dispersing agents in order to remove existing deposits from where they have settled back into the moving stream. We are also recommending a review of the pumping system requirements in order to determine whether adequate flow velocity exists at the hot water system to prevent further rust deposition.

We consider this report very favorable in that it documents the overwhelming volume of pipe at this critical facility in very good condition. At the same time, it defines specific concerns previously unknown, and offers recommendations to address such weakness in advance, and therefore improve the reliability of the mechanical operations.

We provide more detailed comments, analysis, and recommendations in section seven of this report, following our presentation of data in section four. Please contact CorrView International, LLC at any time regarding further clarification or questions regarding this ultrasonic pipe testing report.

Respectfully submitted,

William P. Duncan
President, CorrView International, LLC

- SECTION FOUR -

Detailed Analysis of Individual Pipe Thickness Measurements

Summary: Chill Water

Number of Pipe Locations Tested: 31

Number of Locations Indicating Possible Need For Replacement: 0

Current Wall Thickness Values

Minimum Measured Wall Thickness of All Points Tested:	**0.1330**	Inches
Average Measured Wall Thickness of All Points Tested:	**0.3127**	Inches
Maximum Measured Wall Thickness of All Points Tested:	**0.3740**	Inches

Current Corrosion Rates

Minimum Estimated Corrosion Rate of All Points Tested:	**0.0**	Mils per Year
Average Estimated Corrosion Rate of All Points Tested:	**0.5**	Mils per Year
Maximum Estimated Corrosion Rate of All Points Tested:	**2.6**	Mils per Year

Percentage of Allowable Pipe Loss

Overall Average Percentage of Allowable Loss:	**8.7**	Percent
Highest Individual Percentage of Pipe Loss:	**71.6**	Percent

Remaining Pipe Life

Average Remaining Pipe Life of All Points Tested:	**120.1**	Years
Lowest Remaining Pipe Life of All Points Tested:	**12.6**	Years

General Summary

Corrosion Evaluation Indicates:	**General Pipe Condition Excellent - Some Weakness Exists At Take-offs**
Interior Wall Variance Indicates:	**Significant Pitting Activity**

Location No: 1

Photo File #: phl-1-01.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

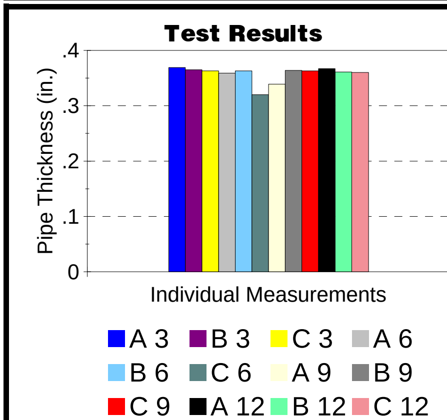
Pipe Identification and Operating Conditions

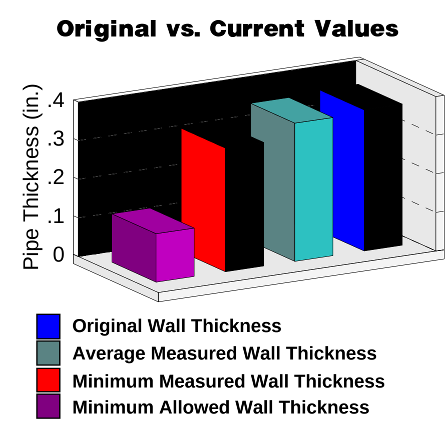
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-101
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return header to pumps. Test points located between pipe support and inlet to pump # 1.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.014 in. / **High to Low Range:** 0.049 in.
Minimum Theoretical Wall Thickness: 0.316 in.
Pitting Index: 10.6% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.358 in.
Average Pipe Loss: 0.007 in.
Corrosion Rate: 0.2 Mils Per Year
Percent of Allowable Pipe Loss: 3.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.320 in.
Maximum Pipe Loss: 0.045 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 18.7 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing at this chill water pipe shows very low wall loss in an area having little outer surface corrosion. This defines relatively low internal corrosion activity. Virtually unlimited service life remains.

Location No: 2

Photo File #: phl-1-02.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

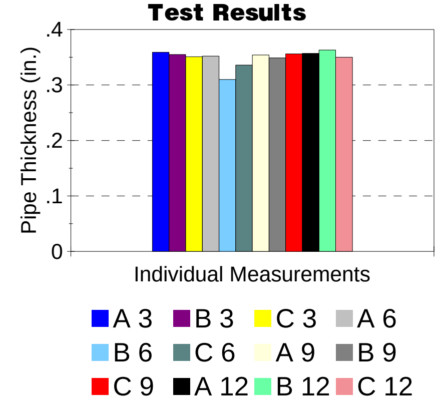
Pipe Identification and Operating Conditions

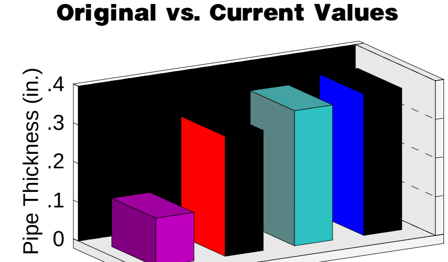
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 60 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-102
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return header to heat exchanger. Test points located between tee from pump # 2 and pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.014 in. / **High to Low Range:** 0.053 in.
Minimum Theoretical Wall Thickness: 0.307 in.
Pitting Index: 11.3% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.349 in.
Average Pipe Loss: 0.016 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 6.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement November 2141

Worst Case Scenario

Minimum Thickness: 0.310 in.
Maximum Pipe Loss: 0.055 in.
Corrosion Rate: 1.7 Mils Per Year
Percent of Allowable Pipe Loss: 22.9 %
Remaining Pipe Life: 106.3 Years
Estimated Retirement March 2123

Testing Indicates: Pipe Condition Excellent

Comments: We measure high average wall thickness not far below new schedule 40 specifications. Some minor pitting also exists. Extremely long service life remains.

Location No: 3

Photo File #: phl-1-06.jpg
Detail: Pipe Location / Condition
Orientation: Side View

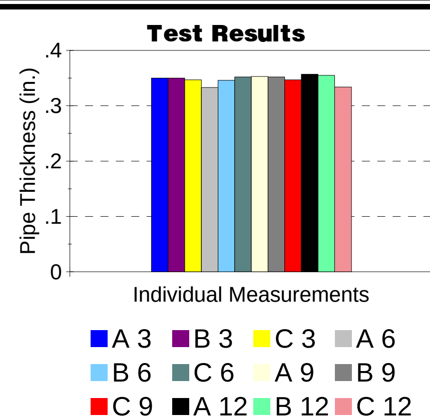
Pipe Identification and Operating Conditions

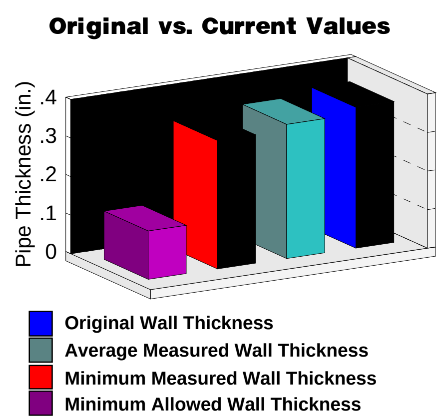
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-103
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 2-4 ft. after 1st pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.008 in. / **High to Low Range:** 0.024 in.
Minimum Theoretical Wall Thickness: 0.325 in.
Pitting Index: 4.3 % - Acceptable Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.348 in.
Average Pipe Loss: 0.017 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 7.1 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.333 in.
Maximum Pipe Loss: 0.032 in.
Corrosion Rate: 1.0 Mils Per Year
Percent of Allowable Pipe Loss: 13.3 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing in this area identifies very high and uniform wall thickness and low average corrosion activity. Virtually unlimited service life remains.

Location No: 4

Photo File #: phl-1-07.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

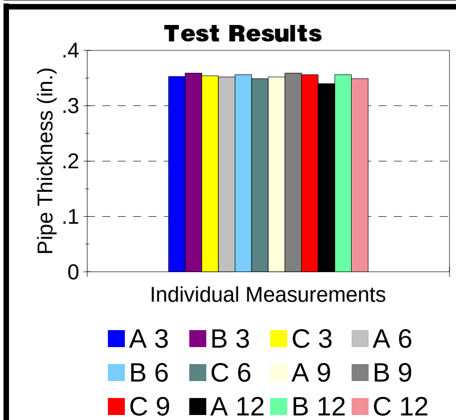
Pipe Identification and Operating Conditions

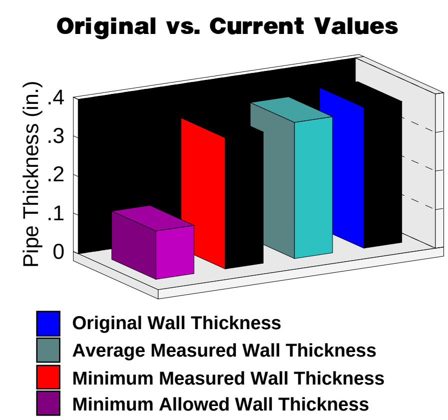
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-104
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return line. Test points located 2-4 ft. after 1st pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.005 in. / **High to Low Range:** 0.019 in.
Minimum Theoretical Wall Thickness: 0.337 in.
Pitting Index: 3.7 % - Acceptable Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.353 in.
Average Pipe Loss: 0.012 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 5.0 %
Remaining Pipe Life: 125.0 Years

Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.340 in.
Maximum Pipe Loss: 0.025 in.
Corrosion Rate: 0.8 Mils Per Year
Percent of Allowable Pipe Loss: 10.4 %
Remaining Pipe Life: 125.0 Years

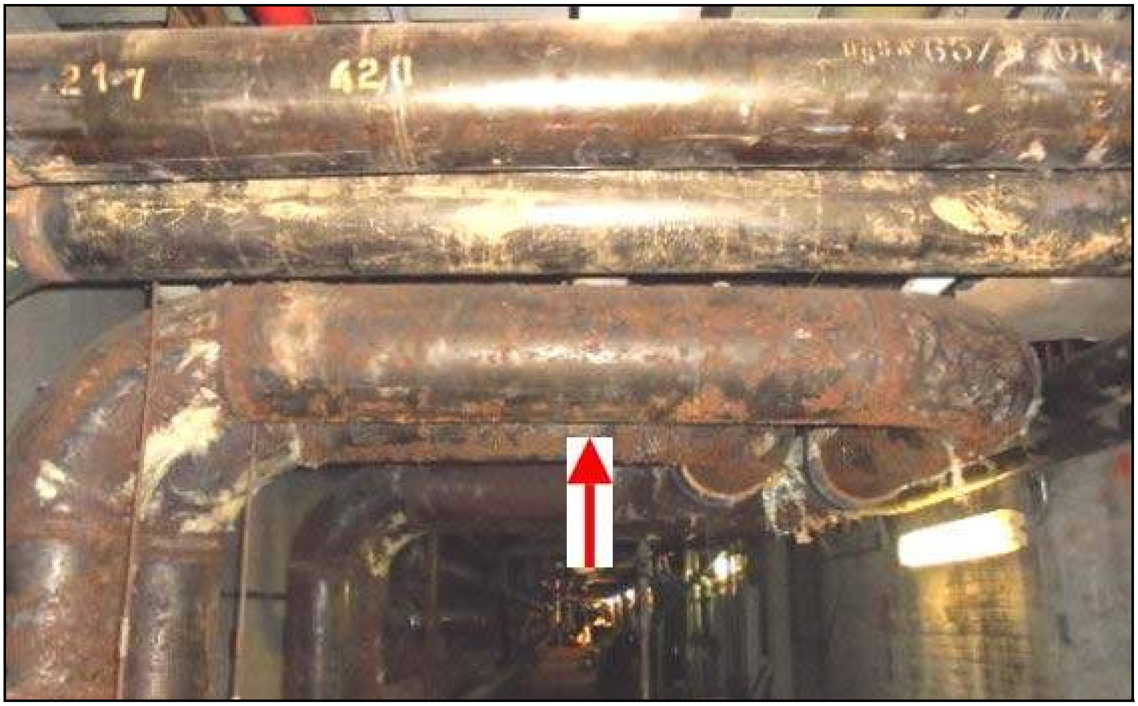
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing produces excellent results at this example of pipe. We measure very high and uniform wall thickness very near new schedule 40 specifications. Corrosion activity is low. Virtually unlimited service life remains.

Location No: 5

Photo File #: phl-1-18.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View



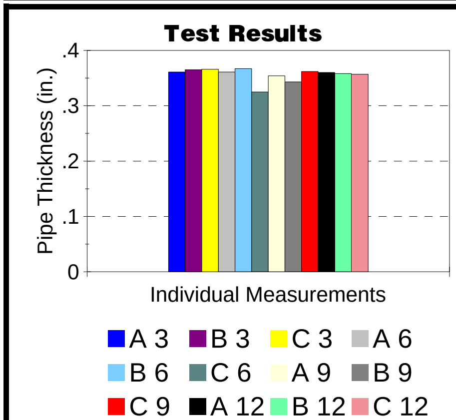
Pipe Identification and Operating Conditions

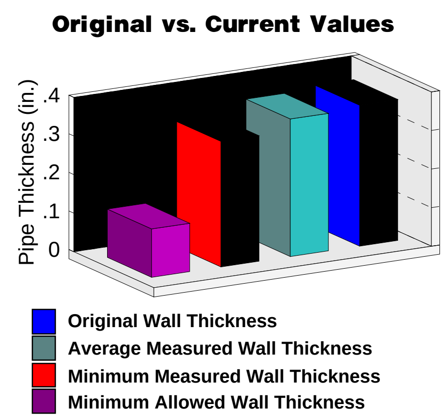
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-106
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line, at expansion loop after 3rd pipe support. Test points located midpoint between 2nd and 3rd elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.042 in.
Minimum Theoretical Wall Thickness: 0.321 in.
Pitting Index: 8.9 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.357 in.
Average Pipe Loss: 0.008 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 3.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.325 in.
Maximum Pipe Loss: 0.040 in.
Corrosion Rate: 1.3 Mils Per Year
Percent of Allowable Pipe Loss: 16.7 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: **Testing shows similar results at this example of pipe but with slightly higher internal pitting activity. Average wall thickness approaches new schedule 40 specifications. Virtually unlimited service life remains.**

Location No: 6

Photo File #: phl-1-19.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

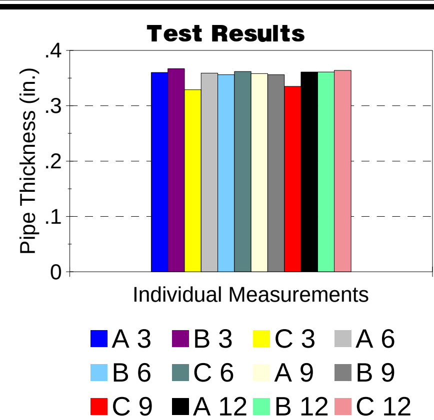
Pipe Identification and Operating Conditions

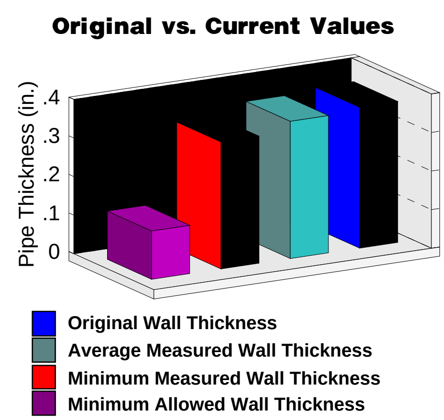
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-107
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return line, at expansion loop after 3rd pipe support. Test points located midpoint between 2nd and 3rd elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.038 in.
Minimum Theoretical Wall Thickness: 0.321 in.
Pitting Index: 7.5 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.356 in.
Average Pipe Loss: 0.009 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 3.9 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.329 in.
Maximum Pipe Loss: 0.036 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 15.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: We produce very similar results at this adjacent return line. Testing shows high average wall thickness very near new schedule 40 specifications. Virtually unlimited service life remains.

Location No: 7

Photo File #: phl-1-24.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

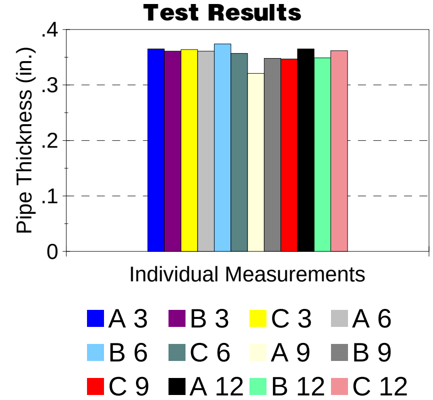
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-108
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 4-6 ft. after 5th pipe support.

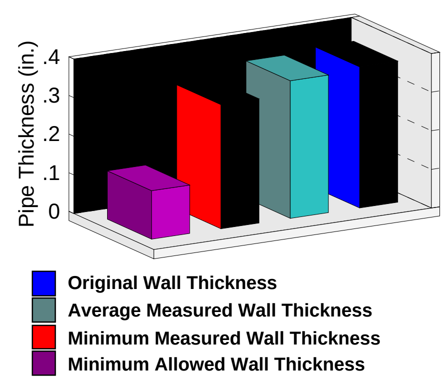
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.014 in. / **High to Low Range:** 0.053 in.
Minimum Theoretical Wall Thickness: 0.315 in.
Pitting Index: 9.9 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.356 in.
Average Pipe Loss: 0.009 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 3.7 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.321 in.
Maximum Pipe Loss: 0.044 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 18.3 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows identical results for this example of chilled water pipe. We measure high average wall thickness very near new pipe specifications. Virtually unlimited service life remains.

Location No: 8

Photo File #: phl-1-25.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

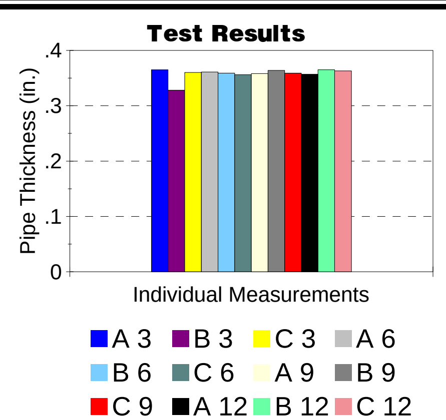
Pipe Identification and Operating Conditions

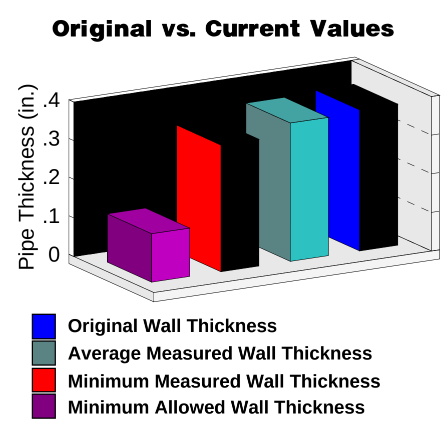
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-109
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return line. Test points located 4-6 ft. after 5th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.037 in.
Minimum Theoretical Wall Thickness: 0.328 in.
Pitting Index: 8.4 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.358 in.
Average Pipe Loss: 0.007 in.
Corrosion Rate: 0.2 Mils Per Year
Percent of Allowable Pipe Loss: 3.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.328 in.
Maximum Pipe Loss: 0.037 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 15.4 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: We produce very similar results at this adjacent return line. Testing shows high average wall thickness very near new schedule 40 specifications. Virtually unlimited service life remains.

Location No: 9

Photo File #: phl-1-31.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

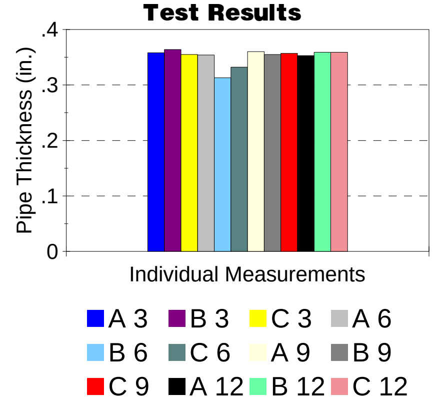
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-110
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 2-4 ft. after 7th pipe support.

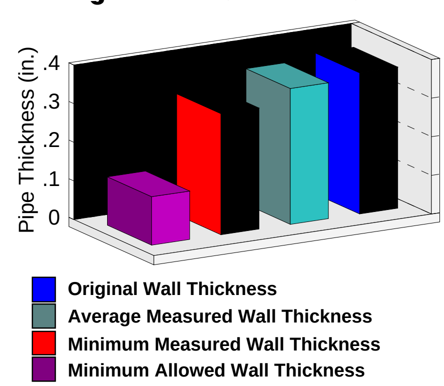
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.014 in. / **High to Low Range:** 0.051 in.
Minimum Theoretical Wall Thickness: 0.308 in.
Pitting Index: 11.0% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.352 in.
Average Pipe Loss: 0.013 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 5.6 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.313 in.
Maximum Pipe Loss: 0.052 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 21.7 %
Remaining Pipe Life: 114.3 Years
Estimated Retirement **March 2131**

Testing Indicates: Pipe Condition Excellent

Comments: Testing shows high average wall thickness. Surface rust is mild and superficial, and has not significantly impacted the pipe. Extremely long service life remains.

Location No: 10

Photo File #: phl-1-32.jpg
Detail: Pipe Location / Condition
Orientation: Side View

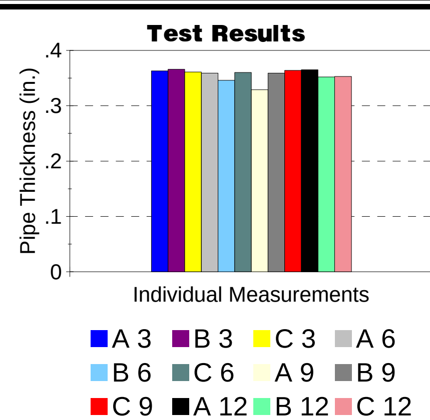
Pipe Identification and Operating Conditions

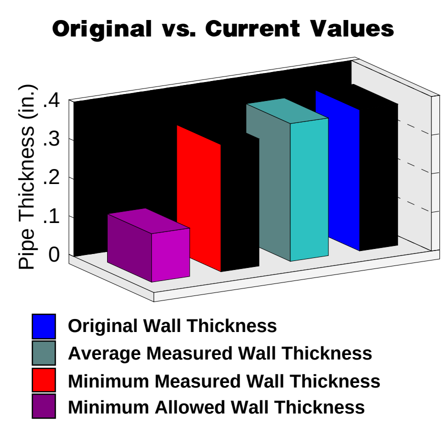
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-111
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return line. Test points located 2-4 ft. after 7th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.037 in.
Minimum Theoretical Wall Thickness: 0.325 in.
Pitting Index: 7.7 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.356 in.
Average Pipe Loss: 0.009 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 3.6 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.329 in.
Maximum Pipe Loss: 0.036 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 15.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing produces excellent results at this example of pipe. We measure very high and uniform average wall thickness very near new schedule 40 specifications. Corrosion activity is low. Virtually unlimited service life remains.

Location No: **11**

Photo File #: phl-1-66.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

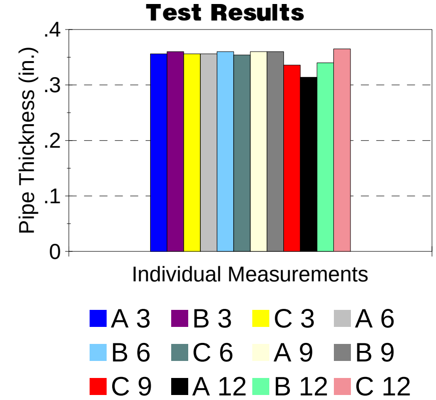
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-112
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 2-4 ft. after 9th pipe support.

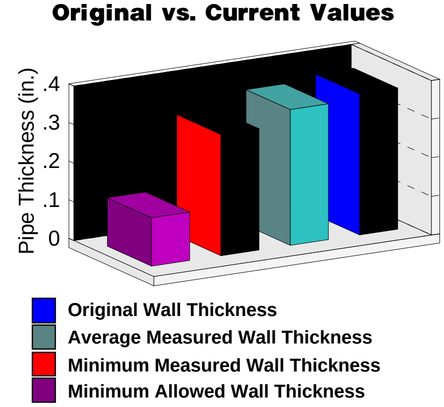
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.365** in.
Minimum Allowable Thickness: **0.125** in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.051 in.
Minimum Theoretical Wall Thickness: 0.308 in.
Pitting Index: 10.6% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: **0.351** in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 5.7 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: **0.314** in.
Maximum Pipe Loss: 0.051 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 21.3 %
Remaining Pipe Life: 117.1 Years
Estimated Retirement **January 2134**

Testing Indicates: Pipe Condition Excellent

Comments: We produce another example showing high average wall thickness not far below new schedule 40 specifications. Some minor pitting exists. Extremely long service life remains.

Location No: 12

Photo File #: phl-1-67.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

Pipe Identification and Operating Conditions

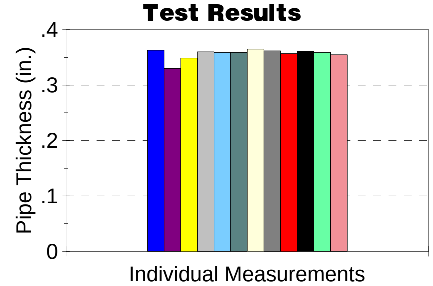
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-113
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main return line. Test points located 2-4 ft. after 9th pipe support.

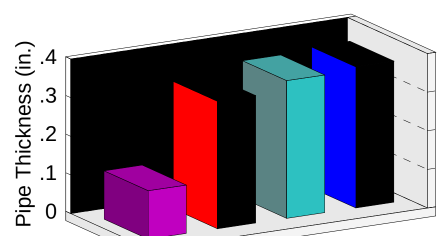
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.009 in. / **High to Low Range:** 0.035 in.
Minimum Theoretical Wall Thickness: 0.329 in.
Pitting Index: 7.5 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.357 in.
Average Pipe Loss: 0.008 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 3.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement November 2141

Worst Case Scenario

Minimum Thickness: 0.330 in.
Maximum Pipe Loss: 0.035 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 14.6 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement November 2141

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows high average wall thickness approaching new schedule 40 specifications. Surface rust is minor and insignificant. Virtually unlimited service life remains.

Location No: 13

Photo File #: phl-1-68.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

Pipe Identification and Operating Conditions

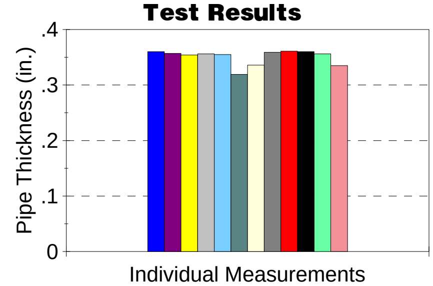
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-114
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 2-4 ft. after 11th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.013 in. / **High to Low Range:** 0.042 in.
Minimum Theoretical Wall Thickness: 0.311 in.
Pitting Index: 9.0 % - Moderate Pitting Activity
Notes: None

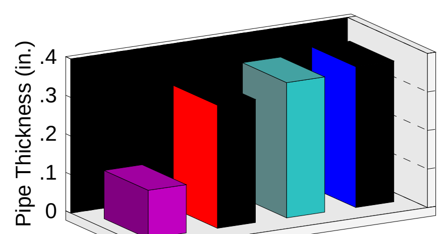
Graphical Summary

Test Results



A 3 B 3 C 3 A 6
B 6 C 6 A 9 B 9
C 9 A 12 B 12 C 12

Original vs. Current Values



Original Wall Thickness
Average Measured Wall Thickness
Minimum Measured Wall Thickness
Minimum Allowed Wall Thickness

Average Case Scenario

Average Thickness: 0.351 in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 6.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.319 in.
Maximum Pipe Loss: 0.046 in.
Corrosion Rate: 1.5 Mils Per Year
Percent of Allowable Pipe Loss: 19.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows high average wall thickness approaching new schedule 40 specifications. Surface rust is minor and insignificant. Virtually unlimited service life remains.

Location No: **14**

Photo File #: phl-1-69.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

Pipe Identification and Operating Conditions

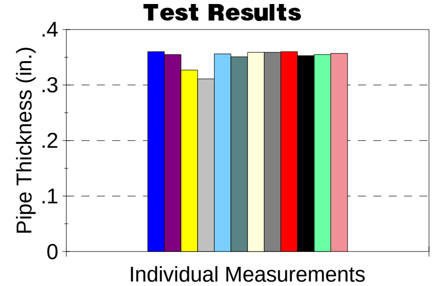
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-115
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 2-4 ft. after 11th pipe support.

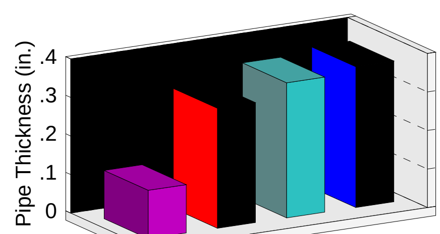
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.365** in.
Minimum Allowable Thickness: **0.125** in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.049 in.
Minimum Theoretical Wall Thickness: 0.305 in.
Pitting Index: 11.2% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: **0.350** in.
Average Pipe Loss: 0.015 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 6.1 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: **0.311** in.
Maximum Pipe Loss: 0.054 in.
Corrosion Rate: 1.7 Mils Per Year
Percent of Allowable Pipe Loss: 22.5 %
Remaining Pipe Life: 108.9 Years
Estimated Retirement **October 2125**

Testing Indicates: Pipe Condition Excellent

Comments: Testing in this area shows minor surface rust having had little impact upon its condition. Average wall thickness is high, with extremely long service life available.

Location No: 15

Photo File #: phl-1-72.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

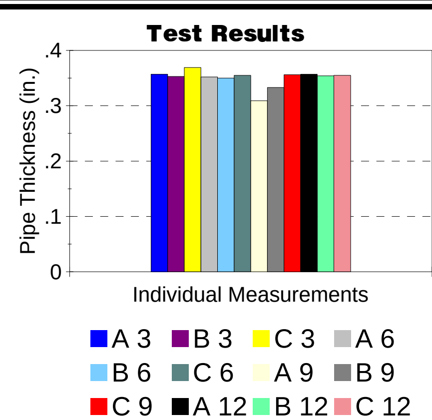
Pipe Identification and Operating Conditions

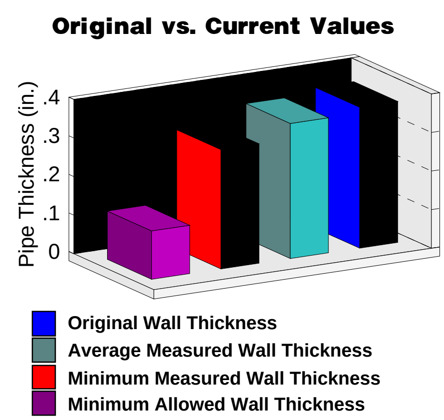
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-116
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 2-4 ft. after 13th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.365 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.060 in.
Minimum Theoretical Wall Thickness: 0.304 in.
Pitting Index: 11.7% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.350 in.
Average Pipe Loss: 0.015 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 6.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

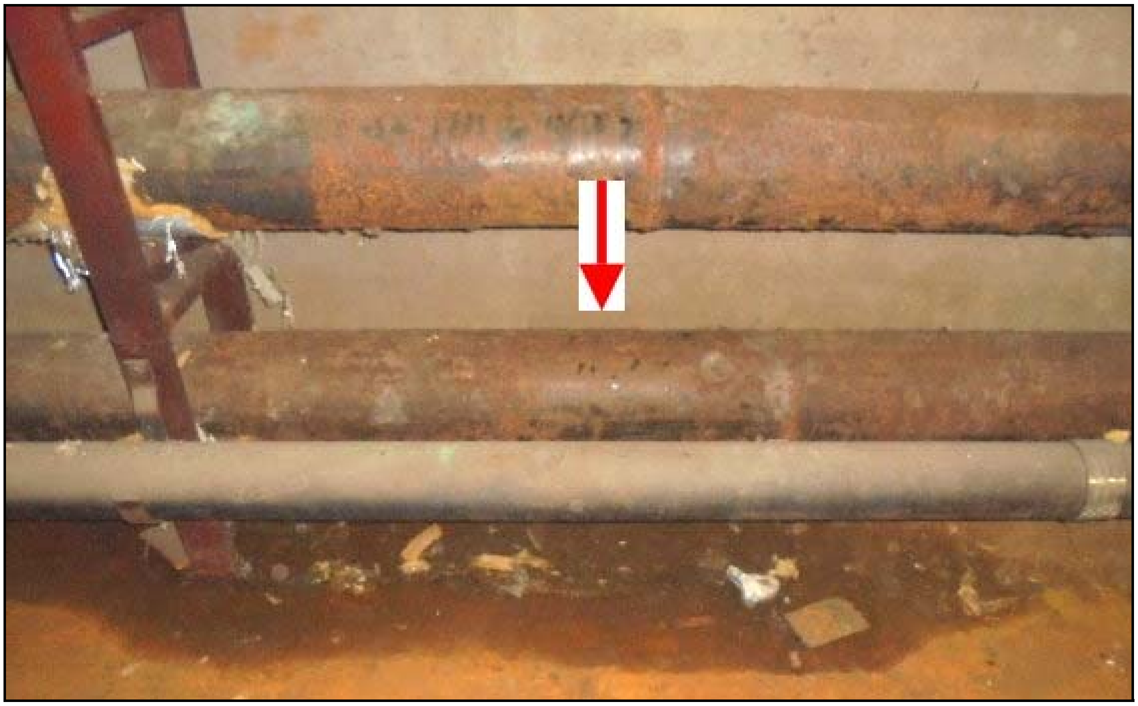
Minimum Thickness: 0.309 in.
Maximum Pipe Loss: 0.056 in.
Corrosion Rate: 1.8 Mils Per Year
Percent of Allowable Pipe Loss: 23.3 %
Remaining Pipe Life: 103.8 Years
Estimated Retirement **October 2120**

Testing Indicates: Pipe Condition Excellent

Comments: We show another example of high average wall thickness and only mild - moderate impact due to outer surface corrosion. Extremely long service life remains.

Location No: 16

Photo File #: phl-1-73.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View



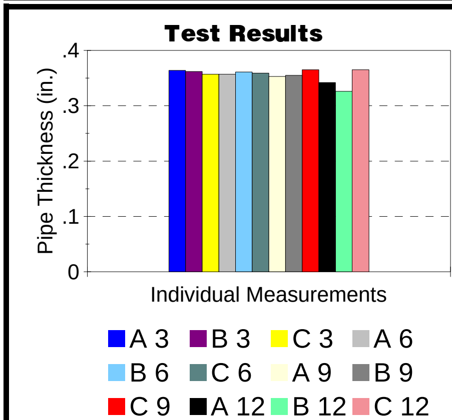
Pipe Identification and Operating Conditions

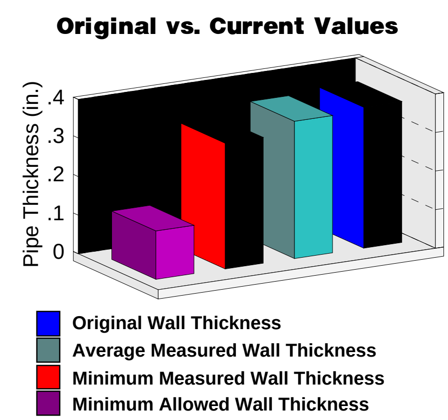
Service: Chill Water
Nominal Pipe Size: 10 in.
Actual Pipe Size: 10.75 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-10-117
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 2-4 ft. after 13th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.365** in.
Minimum Allowable Thickness: **0.125** in. (0.033)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.039 in.
Minimum Theoretical Wall Thickness: 0.322 in.
Pitting Index: 8.3 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: **0.356** in.
Average Pipe Loss: 0.010 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 4.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: **0.326** in.
Maximum Pipe Loss: 0.039 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 16.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows high average wall thickness approaching new schedule 40 specifications. Surface rust is minor and insignificant. Virtually unlimited service life remains.

Location No: 17

Photo File #: phl-1-78.jpg
Detail: Pipe Location / Condition
Orientation: Side View

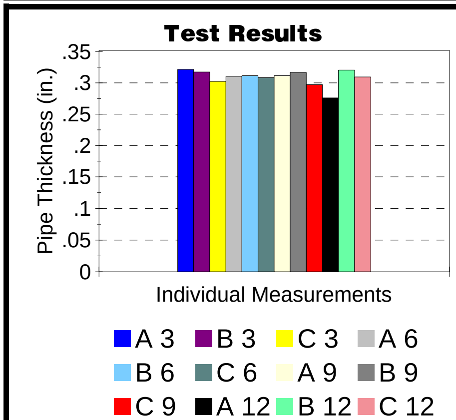
Pipe Identification and Operating Conditions

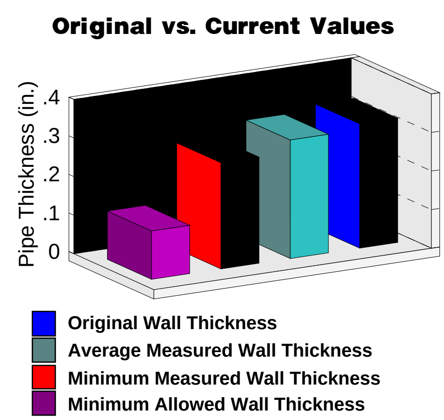
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-118
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main supply line. Test points located 2-4 ft. after 16th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.032)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.045 in.
Minimum Theoretical Wall Thickness: 0.270 in.
Pitting Index: 10.5% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.307 in.
Average Pipe Loss: 0.015 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 7.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.275 in.
Maximum Pipe Loss: 0.047 in.
Corrosion Rate: 1.5 Mils Per Year
Percent of Allowable Pipe Loss: 23.9 %
Remaining Pipe Life: 100.9 Years
Estimated Retirement **October 2117**

Testing Indicates: Pipe Condition Excellent

Comments: We measure very high average wall thickness not far below new schedule 40 specifications. Corrosion activity would be considered low, with mild pitting. Extremely long service life remains.

Location No: 18

Photo File #: phl-1-77.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

Pipe Identification and Operating Conditions

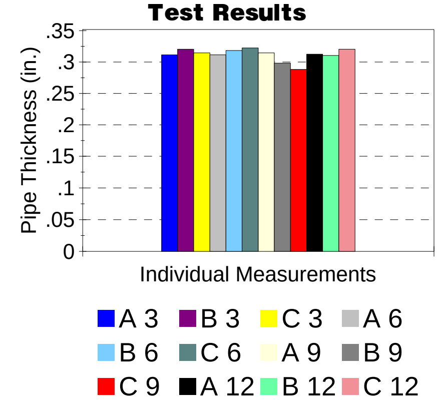
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-119
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 2-4 ft. after 16th pipe support.

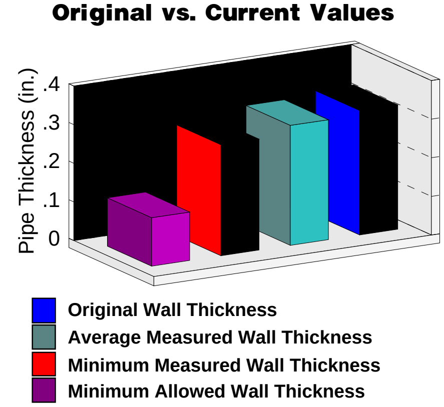
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.322** in.
Minimum Allowable Thickness: **0.125** in. (0.029)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.034 in.
Minimum Theoretical Wall Thickness: 0.281 in.
Pitting Index: 7.6 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: **0.311** in.
Average Pipe Loss: 0.012 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 5.8 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: **0.287** in.
Maximum Pipe Loss: 0.035 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 17.8 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows high average wall thickness approaching new schedule 40 specifications. Surface rust is minor and insignificant. Virtually unlimited service life remains.

Location No: 19

Photo File #: phl-1-116.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

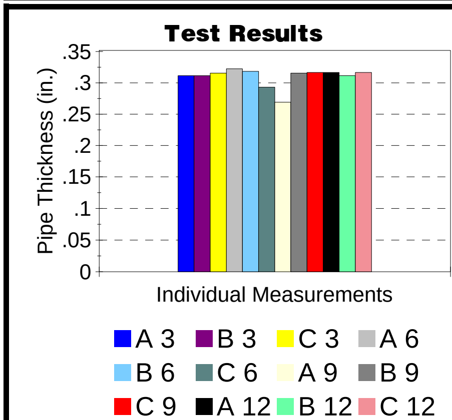
Pipe Identification and Operating Conditions

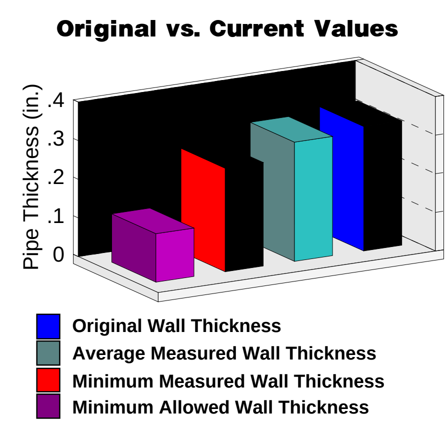
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-122
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 1-3 ft. after 19th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.032)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.053 in.
Minimum Theoretical Wall Thickness: 0.265 in.
Pitting Index: 13.1% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.308 in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 6.9 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

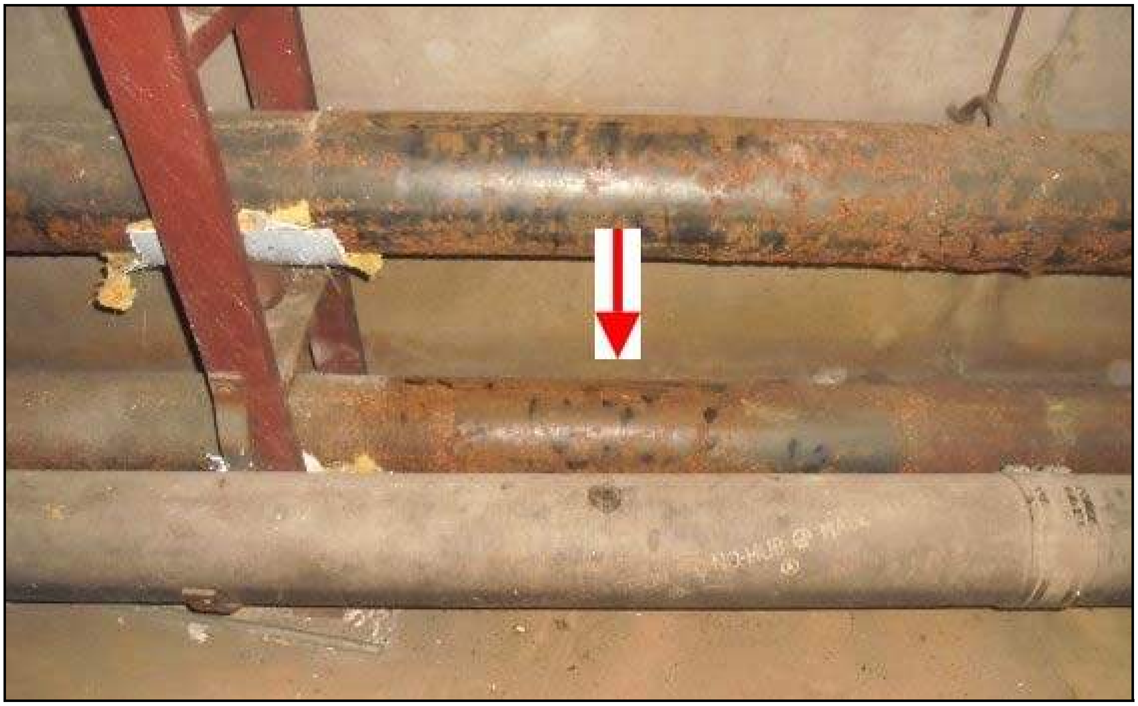
Minimum Thickness: 0.268 in.
Maximum Pipe Loss: 0.054 in.
Corrosion Rate: 1.7 Mils Per Year
Percent of Allowable Pipe Loss: 27.4 %
Remaining Pipe Life: 83.7 Years
Estimated Retirement **August 2100**

Testing Indicates: Pipe Condition Excellent

Comments: Our testing shows deeper internal pitting at this example of pipe given that outer surface rust is only minor. Extremely long service life remains.

Location No: 20

Photo File #: phl-1-117.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View



Pipe Identification and Operating Conditions

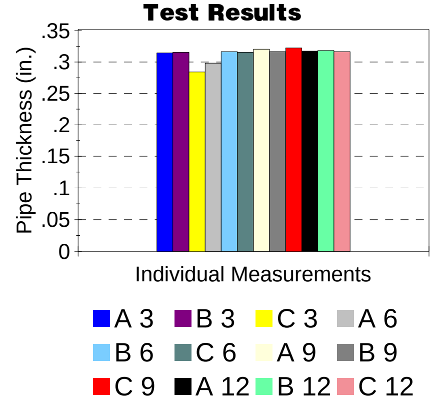
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-123
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 1-3 ft. after 19th pipe support.

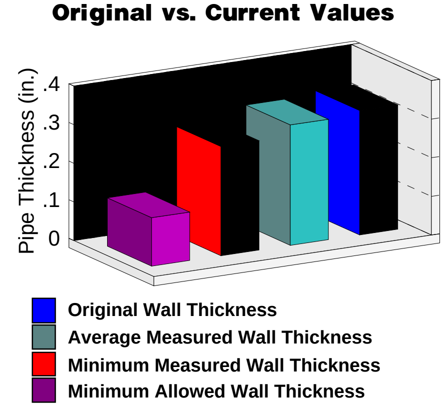
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.029)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.038 in.
Minimum Theoretical Wall Thickness: 0.279 in.
Pitting Index: 9.2 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.312 in.
Average Pipe Loss: 0.010 in.
Corrosion Rate: 0.3 Mils Per Year
Percent of Allowable Pipe Loss: 5.3 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement November 2141

Worst Case Scenario

Minimum Thickness: 0.283 in.
Maximum Pipe Loss: 0.039 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 19.8 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement November 2141

Testing Indicates: Unlimited Service Life Remains

Comments: We measure very high average wall thickness closely approaching new schedule 40 specifications. Average corrosion activity is very low. Virtually unlimited service life remains.

Location No: 21

Photo File #: phl-1-123.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

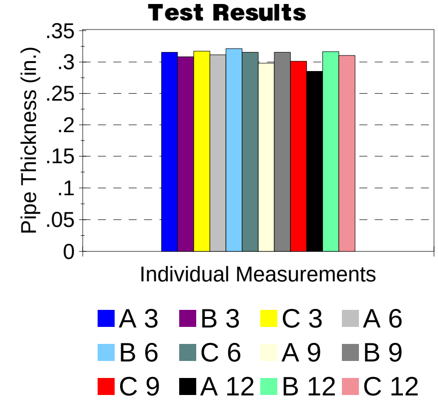
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-124
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 3-5 ft. after 23rd pipe support.

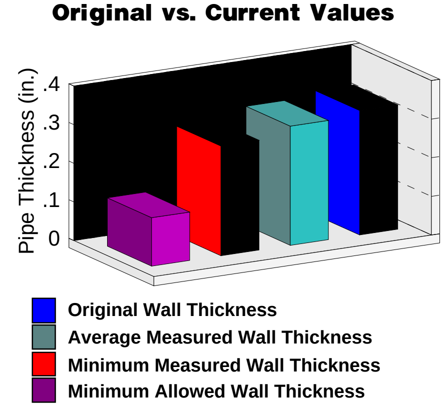
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.032)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.036 in.
Minimum Theoretical Wall Thickness: 0.278 in.
Pitting Index: 7.9 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.308 in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 6.9 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.284 in.
Maximum Pipe Loss: 0.038 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 19.3 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows high average wall thickness with some mild internal pitting. Corrosion activity would be considered low. Virtually unlimited service life remains.

Location No: 22

Photo File #: phl-1-127.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

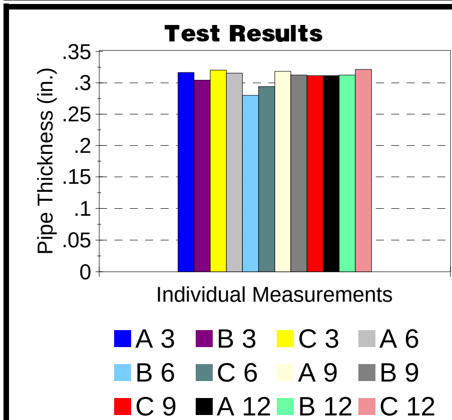
Pipe Identification and Operating Conditions

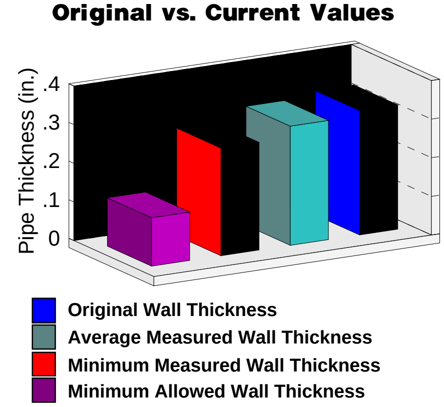
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-125
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 3-5 ft. after 23rd pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.029)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.041 in.
Minimum Theoretical Wall Thickness: 0.273 in.
Pitting Index: 9.6 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.309 in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 6.9 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.279 in.
Maximum Pipe Loss: 0.043 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 21.8 %
Remaining Pipe Life: 113.2 Years
Estimated Retirement **February 2130**

Testing Indicates: Pipe Condition Excellent

Comments: We identify high average wall thickness at this example of pipe. Minor surface rust also exists but has no significant impact upon pipe condition. Extremely long service life remains.

Location No: 23

Photo File #: phl-1-131.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

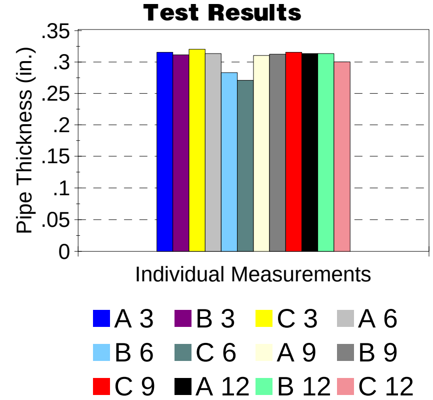
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-126
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Chill water main supply line. Test points located 1-24 in. after 27th pipe support.

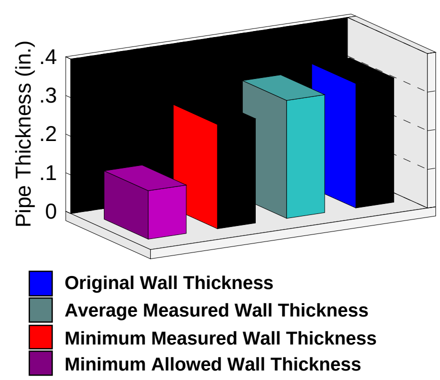
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.032)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.049 in.
Minimum Theoretical Wall Thickness: 0.261 in.
Pitting Index: 11.6% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.305 in.
Average Pipe Loss: 0.017 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 8.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.270 in.
Maximum Pipe Loss: 0.052 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 26.4 %
Remaining Pipe Life: 88.1 Years
Estimated Retirement **January 2105**

Testing Indicates: Pipe Condition Excellent

Comments: Testing in this area again shows some mild internal pitting activity but no significant wall loss. Corrosion activity would be considered normal. Extremely long service life remains.

Location No: 24

Photo File #: phl-1-132.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

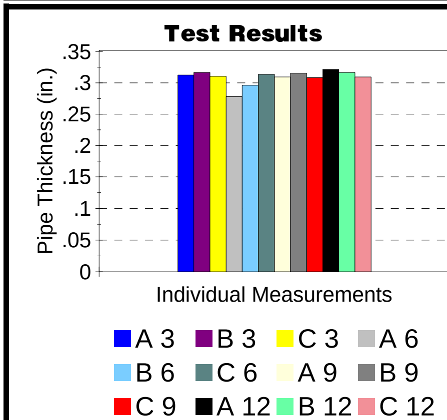
Pipe Identification and Operating Conditions

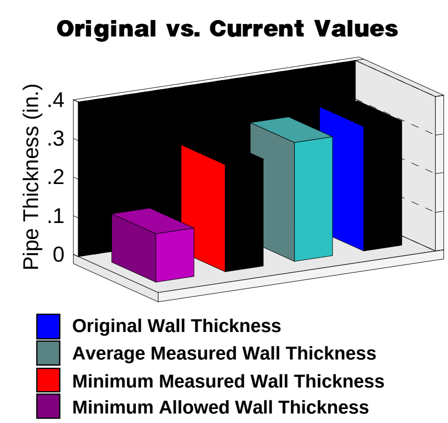
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-127
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 1-24 in. after 27th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.029)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.043 in.
Minimum Theoretical Wall Thickness: 0.273 in.
Pitting Index: 9.9 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.308 in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 7.3 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.277 in.
Maximum Pipe Loss: 0.045 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 22.8 %
Remaining Pipe Life: 106.7 Years
Estimated Retirement **September 2123**

Testing Indicates: Pipe Condition Excellent

Comments: We identify high average wall thickness at this example of pipe. Minor surface rust also exists but has no significant impact upon pipe condition. Extremely long service life remains.

Location No: 25

Photo File #: phl-1-140.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

Pipe Identification and Operating Conditions

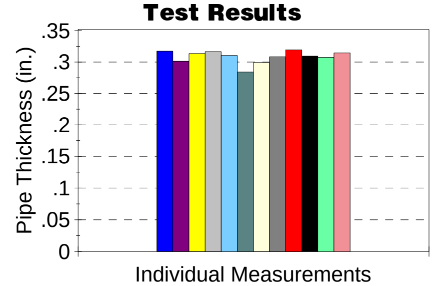
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-130
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main supply line. Test points located 1-3 ft. after 30th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.032)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.035 in.
Minimum Theoretical Wall Thickness: 0.278 in.
Pitting Index: 7.8 % - Moderate Pitting Activity
Notes: None

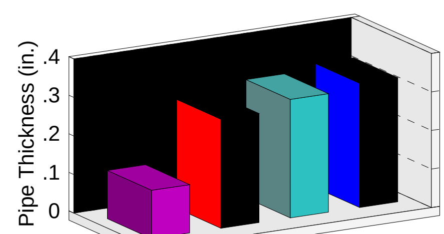
Graphical Summary

Test Results



A 3, B 3, C 3, A 6, B 6, C 6, A 9, B 9, C 9, A 12, B 12, C 12

Original vs. Current Values



- Original Wall Thickness
- Average Measured Wall Thickness
- Minimum Measured Wall Thickness
- Minimum Allowed Wall Thickness

Average Case Scenario

Average Thickness: 0.307 in.
Average Pipe Loss: 0.015 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 7.6 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.283 in.
Maximum Pipe Loss: 0.039 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 19.8 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing shows high average wall thickness with some mild internal pitting. Corrosion activity would be considered normal. Virtually unlimited service life remains.

Location No: 26

Photo File #: phl-1-141.jpg
Detail: Pipe Location / Condition
Orientation: Above Side View

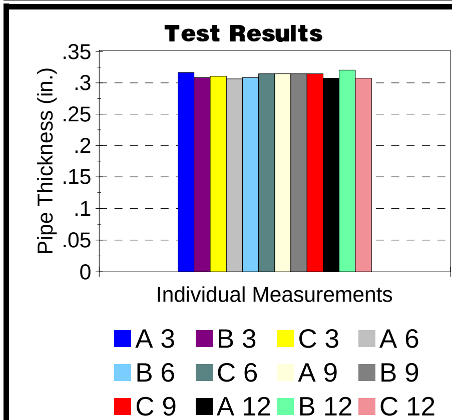
Pipe Identification and Operating Conditions

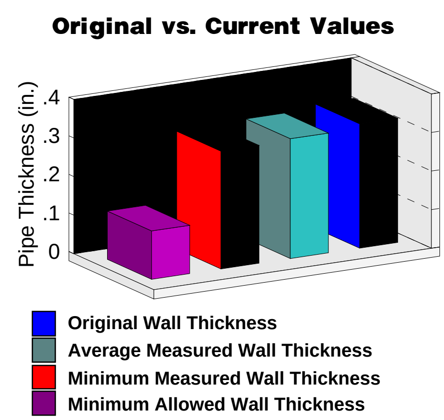
Service: Chill Water
Nominal Pipe Size: 8 in.
Actual Pipe Size: 8.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-CHW-8-131
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Chill water main return line. Test points located 1-3 ft. after 30th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.322 in.
Minimum Allowable Thickness: 0.125 in. (0.029)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.004 in. / **High to Low Range:** 0.014 in.
Minimum Theoretical Wall Thickness: 0.297 in.
Pitting Index: 1.8 % - Insignificant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.311 in.
Average Pipe Loss: 0.011 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 5.8 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.305 in.
Maximum Pipe Loss: 0.017 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 8.6 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Testing Indicates: Unlimited Service Life Remains

Comments: Testing at this example of pipe shows extremely high and uniform wall thickness still near new pipe specifications. Corrosion activity is low. Virtually unlimited service life remains.

Location No: **27**

Photo File #: phl-1-12.jpg
Detail: Pipe Location / Condition
Orientation: Side View

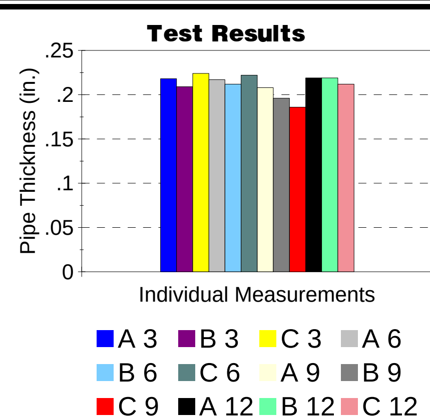
Pipe Identification and Operating Conditions

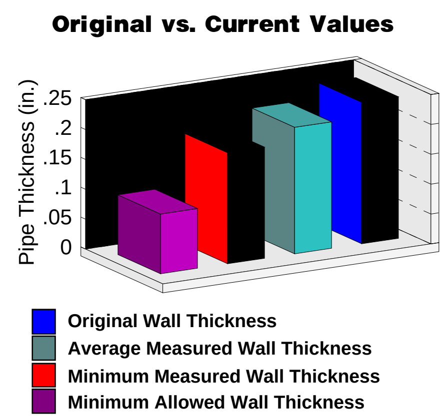
Service: Chill Water
Nominal Pipe Size: 4 in.
Actual Pipe Size: 4.50 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-CHW-4-105
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 1st chill water take-off from main supply line. Test points located between weldolet at main and elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.237 in.
Minimum Allowable Thickness: 0.100 in. (0.024)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.038 in.
Minimum Theoretical Wall Thickness: 0.178 in.
Pitting Index: 12.2% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.212 in.
Average Pipe Loss: 0.025 in.
Corrosion Rate: 0.8 Mils Per Year
Percent of Allowable Pipe Loss: 18.4 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.186 in.
Maximum Pipe Loss: 0.051 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 37.2 %
Remaining Pipe Life: 53.3 Years
Estimated Retirement **April 2070**

Testing Indicates: Pipe Condition Very Good

Comments: Testing at the small diameter take off-line show similar corrosion activity to the large diameter pipe. Average wall thickness is still high, with very long service life remaining.

Location No: 28

Photo File #: phl-1-84.jpg
Detail: Pipe Location / Condition
Orientation: Side View

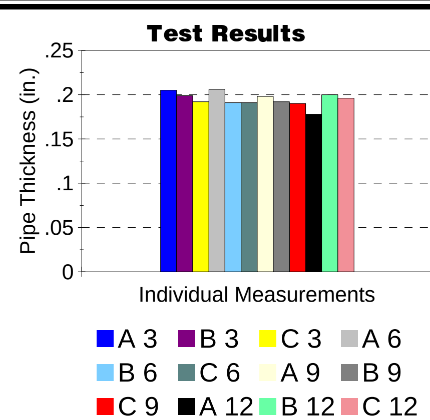
Pipe Identification and Operating Conditions

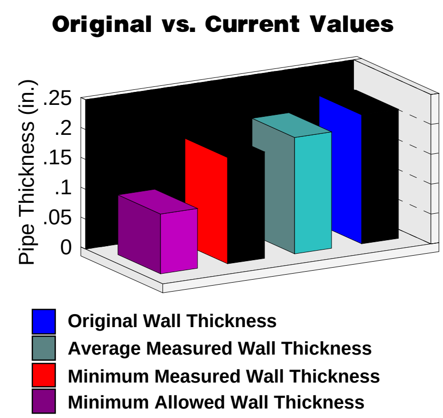
Service: Chill Water
Nominal Pipe Size: 3 in.
Actual Pipe Size: 3.50 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-CHW-3-120
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 5th chill water take-off from main supply line. Test points located between weldolet at main and elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.216 in.
Minimum Allowable Thickness: 0.100 in. (0.022)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.008 in. / **High to Low Range:** 0.028 in.
Minimum Theoretical Wall Thickness: 0.172 in.
Pitting Index: 8.6 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.195 in.
Average Pipe Loss: 0.021 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 18.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.178 in.
Maximum Pipe Loss: 0.038 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 32.8 %
Remaining Pipe Life: 64.9 Years
Estimated Retirement **October 2081**

Testing Indicates: Pipe Condition Very Good

Comments: We measure similar corrosion activity at this take-off line. Testing shows still high average wall thickness not far below new schedule 40 specifications. Very long service life remains.

Location No: 29

Photo File #: phl-1-85.jpg
Detail: Pipe Location / Condition
Orientation: Side View

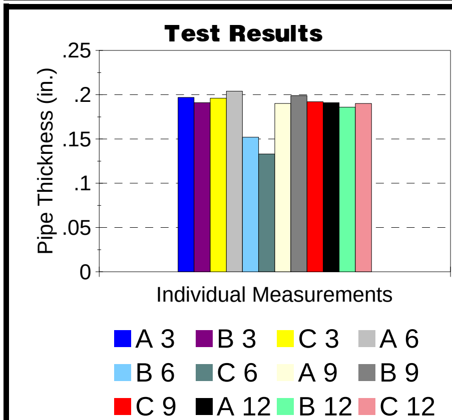
Pipe Identification and Operating Conditions

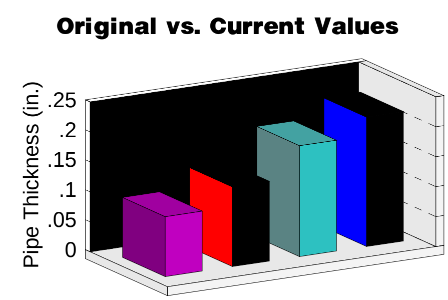
Service: Chill Water
Nominal Pipe Size: 3 in.
Actual Pipe Size: 3.50 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-CHW-3-121
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 5th chill water take-off from main return line. Test points located between weldolet at main and elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.216 in.
Minimum Allowable Thickness: 0.100 in. (0.021)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.021 in. / **High to Low Range:** 0.071 in.
Minimum Theoretical Wall Thickness: 0.123 in.
Pitting Index: 28.1% - High Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.185 in.
Average Pipe Loss: 0.031 in.
Corrosion Rate: 1.0 Mils Per Year
Percent of Allowable Pipe Loss: 26.7 %
Remaining Pipe Life: 87.0 Years
Estimated Retirement **November 2103**

Worst Case Scenario

Minimum Thickness: 0.133 in.
Maximum Pipe Loss: 0.083 in.
Corrosion Rate: 2.6 Mils Per Year
Percent of Allowable Pipe Loss: 71.6 %
Remaining Pipe Life: 12.6 Years
Estimated Retirement **July 2029**

Testing Indicates: Pipe Condition Satisfactory

Comments: Testing at another example of 3 in. take-off line shows much deeper outer surface pitting activity resulting in a far lesser service life estimate. Acceptable service life remains.

Location No: 30

Photo File #: phl-1-138.jpg
Detail: Pipe Location / Condition
Orientation: Side View

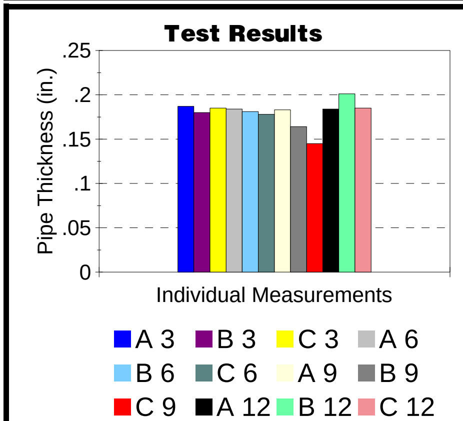
Pipe Identification and Operating Conditions

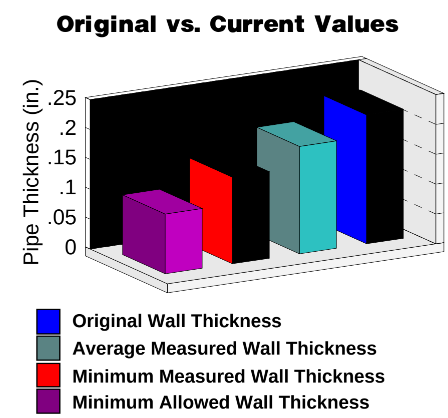
Service: Chill Water
Nominal Pipe Size: 3 in.
Actual Pipe Size: 3.50 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 65 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-CHW-3-128
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 8th chill water take-off from main supply line, after 27th pipe support. Test points located between weldolet at main and elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.216 in.
Minimum Allowable Thickness: 0.100 in. (0.022)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.014 in. / **High to Low Range:** 0.056 in.
Minimum Theoretical Wall Thickness: 0.139 in.
Pitting Index: 19.3% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.180 in.
Average Pipe Loss: 0.036 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 31.3 %
Remaining Pipe Life: 69.5 Years
Estimated Retirement **June 2086**

Worst Case Scenario

Minimum Thickness: 0.145 in.
Maximum Pipe Loss: 0.071 in.
Corrosion Rate: 2.2 Mils Per Year
Percent of Allowable Pipe Loss: 61.2 %
Remaining Pipe Life: 20.0 Years
Estimated Retirement **January 2037**

Testing Indicates: Pipe Condition Satisfactory

Comments: Testing at this example of pipe also shows some higher outer surface pitting activity. Such higher pitting has a greater impact against small diameter pipe of lesser wall thickness. Long service life still remains.

Location No: 31

Photo File #: phl-1-139.jpg
Detail: Pipe Location / Condition
Orientation: Side View

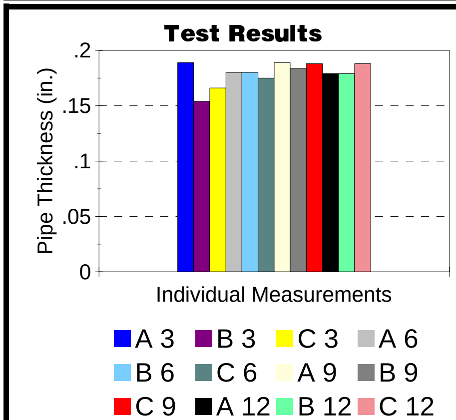
Pipe Identification and Operating Conditions

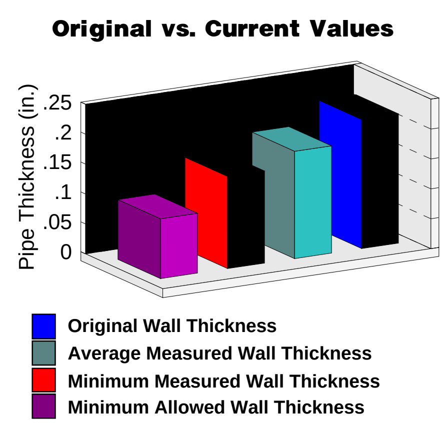
Service: Chill Water
Nominal Pipe Size: 3 in.
Actual Pipe Size: 3.50 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To HX
Pipe Pressure: 50 PSIG
Temperature: 55 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-CHW-3-129
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 8th chill water take-off from main return line, after 27th pipe support. Test points located between weldolet at main and elbow.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.216 in.
Minimum Allowable Thickness: 0.100 in. (0.021)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.035 in.
Minimum Theoretical Wall Thickness: 0.148 in.
Pitting Index: 14.1% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.179 in.
Average Pipe Loss: 0.037 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 31.7 %
Remaining Pipe Life: 68.2 Years
Estimated Retirement **February 2085**

Worst Case Scenario

Minimum Thickness: 0.154 in.
Maximum Pipe Loss: 0.062 in.
Corrosion Rate: 2.0 Mils Per Year
Percent of Allowable Pipe Loss: 53.4 %
Remaining Pipe Life: 27.5 Years
Estimated Retirement **July 2044**

Testing Indicates: Pipe Condition Good

Comments: We produce similar results at this example of pipe. Testing shows higher than normal corrosion and pitting activity but still long service life remaining.

Summary: Hot Water Heating

Number of Pipe Locations Tested: 28

Number of Locations Indicating Possible Need For Replacement: 2

Current Wall Thickness Values

Minimum Measured Wall Thickness of All Points Tested:	**0.0780**	Inches
Average Measured Wall Thickness of All Points Tested:	**0.2203**	Inches
Maximum Measured Wall Thickness of All Points Tested:	**0.2850**	Inches

Current Corrosion Rates

Minimum Estimated Corrosion Rate of All Points Tested:	**0.0**	Mils per Year
Average Estimated Corrosion Rate of All Points Tested:	**0.8**	Mils per Year
Maximum Estimated Corrosion Rate of All Points Tested:	**3.0**	Mils per Year

Percentage of Allowable Pipe Loss

Overall Average Percentage of Allowable Loss:	**23.8**	Percent
Highest Individual Percentage of Pipe Loss:	**100.0**	Percent

Remaining Pipe Life

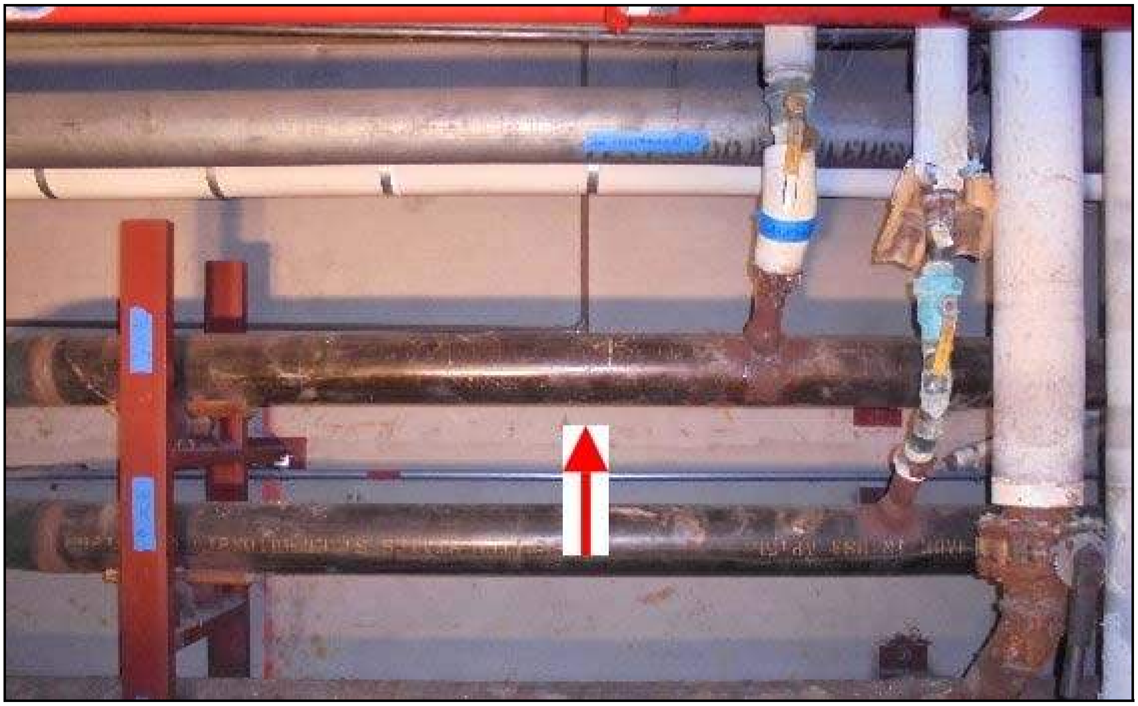
Average Remaining Pipe Life of All Points Tested:	**101.0**	Years
Lowest Remaining Pipe Life of All Points Tested:	**0.0**	Years

General Summary

Corrosion Evaluation Indicates:	**General Pipe Condition Very Good - Some Pipe Approaching Failure**
Interior Wall Variance Indicates:	**Significant Pitting Activity**

Location No: 32

Photo File #: phl-1-03.jpg
Detail: Pipe Location / Condition
Orientation: Side View



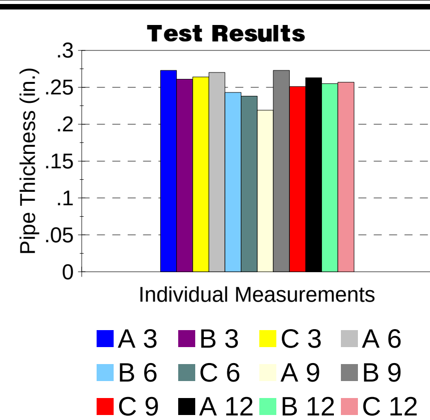
Pipe Identification and Operating Conditions

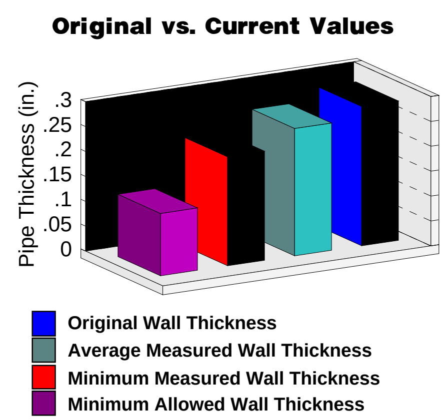
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-01
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 2-4 ft. after 1st pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.016 in. / **High to Low Range:** 0.054 in.
Minimum Theoretical Wall Thickness: 0.208 in.
Pitting Index: 14.3% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.256 in.
Average Pipe Loss: 0.024 in.
Corrosion Rate: 0.8 Mils Per Year
Percent of Allowable Pipe Loss: 15.8 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.219 in.
Maximum Pipe Loss: 0.061 in.
Corrosion Rate: 1.9 Mils Per Year
Percent of Allowable Pipe Loss: 39.4 %
Remaining Pipe Life: 48.7 Years
Estimated Retirement **August 2065**

Testing Indicates: Pipe Condition Good

Comments: **Having no outer surface corrosion at this hot water line, all wall loss can be attributed due to a higher than normal inner corrosion and pitting condition. Corrosion activity would be expected at near 0.5 MPY, and more uniform.**

Location No: **33**

Photo File #: phl-1-04.jpg
Detail: Pipe Location / Condition
Orientation: Side View

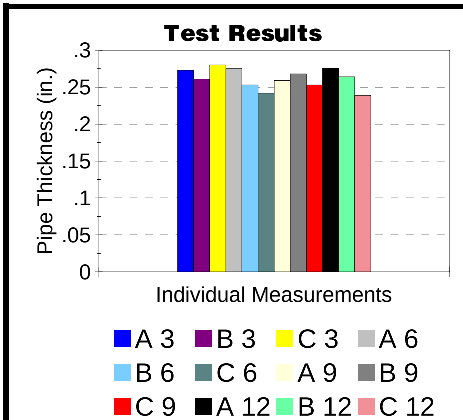
Pipe Identification and Operating Conditions

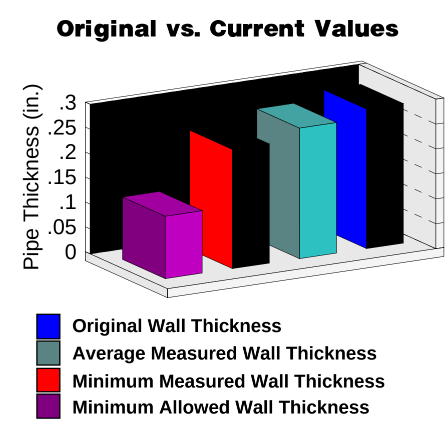
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-02
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 2-4 ft. after 1st pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.013 in. / **High to Low Range:** 0.041 in.
Minimum Theoretical Wall Thickness: 0.222 in.
Pitting Index: 8.7 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.262 in.
Average Pipe Loss: 0.018 in.
Corrosion Rate: 0.6 Mils Per Year
Percent of Allowable Pipe Loss: 11.7 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.239 in.
Maximum Pipe Loss: 0.041 in.
Corrosion Rate: 1.3 Mils Per Year
Percent of Allowable Pipe Loss: 26.5 %
Remaining Pipe Life: 87.9 Years
Estimated Retirement **October 2104**

Testing Indicates: Pipe Condition Excellent

Comments: Testing at the adjacent return line shows more favorable results and less pitting activity. Average wall thickness is still very high. Extremely long service life remains.

Location No: 34

Photo File #: phl-1-16.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

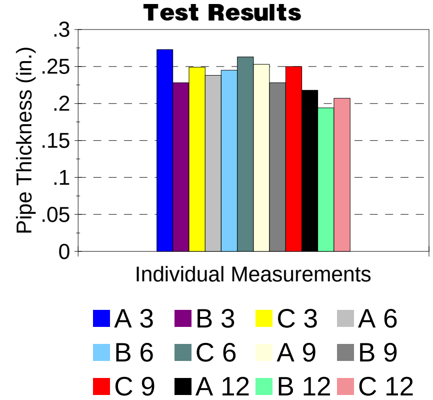
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-04
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line, at expansion loop after 3rd pipe support. Test points located midpoint between 2nd and 3rd elbow.

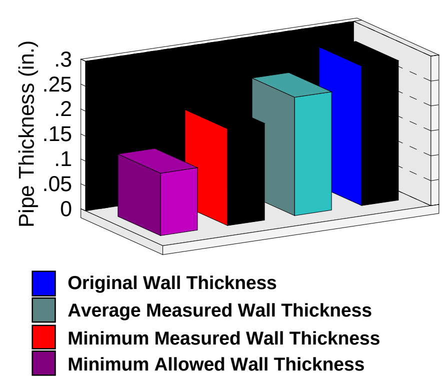
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.023 in. / **High to Low Range:** 0.079 in.
Minimum Theoretical Wall Thickness: 0.168 in.
Pitting Index: 18.2% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.237 in.
Average Pipe Loss: 0.043 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 27.6 %
Remaining Pipe Life: 82.8 Years
Estimated Retirement **September 2099**

Worst Case Scenario

Minimum Thickness: 0.194 in.
Maximum Pipe Loss: 0.086 in.
Corrosion Rate: 2.7 Mils Per Year
Percent of Allowable Pipe Loss: 55.5 %
Remaining Pipe Life: 25.4 Years
Estimated Retirement **May 2042**

Testing Indicates: Pipe Condition Good

Comments: Testing at this example of pipe shows much higher corrosion and pitting activity which well exceeds normal conditions. Highest pitting activity is approximately 5 times above normal. Long service life remains.

Location No: 35

Photo File #: phl-1-17.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

Pipe Identification and Operating Conditions

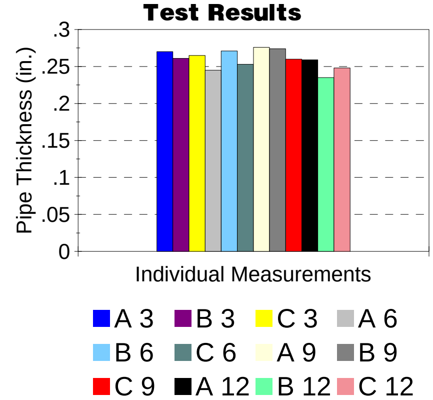
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-05
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line, at expansion loop after 3rd pipe support. Test points located midpoint between 2nd and 3rd elbow.

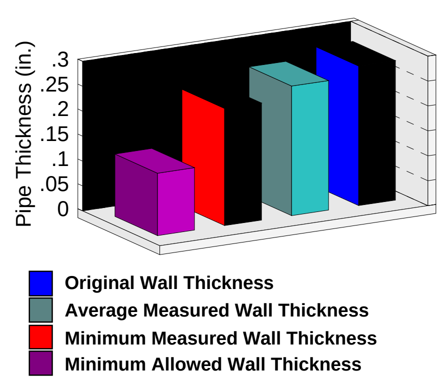
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.013 in. / **High to Low Range:** 0.041 in.
Minimum Theoretical Wall Thickness: 0.222 in.
Pitting Index: 9.5 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.260 in.
Average Pipe Loss: 0.020 in.
Corrosion Rate: 0.6 Mils Per Year
Percent of Allowable Pipe Loss: 13.1 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

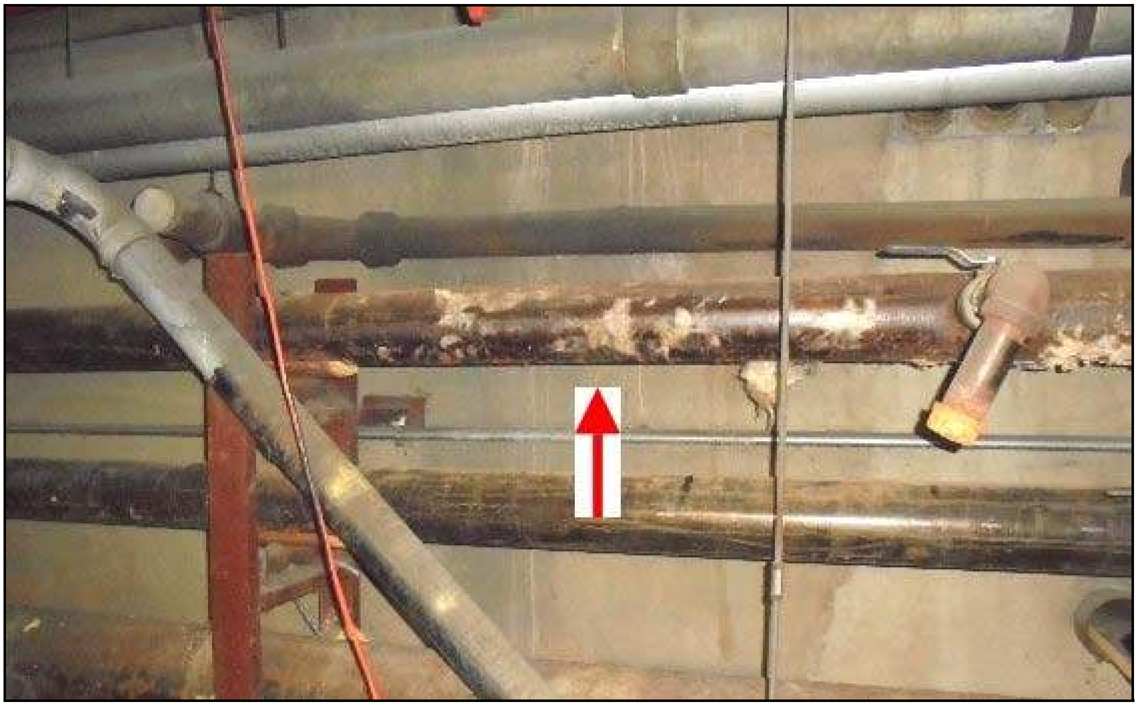
Minimum Thickness: 0.235 in.
Maximum Pipe Loss: 0.045 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 29.0 %
Remaining Pipe Life: 77.3 Years
Estimated Retirement **March 2094**

Testing Indicates: Pipe Condition Excellent

Comments: We measure noticeably better results at this example of return pipe. Corrosion is much lower and more uniform to present far less threat. Extremely long service life remains.

Location No: 36

Photo File #: phl-1-26.jpg
Detail: Pipe Location / Condition
Orientation: Side View



Pipe Identification and Operating Conditions

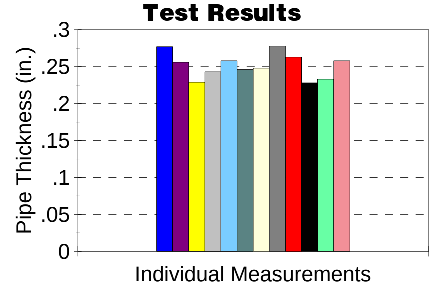
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-06
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 2-4 ft. after 5th pipe support.

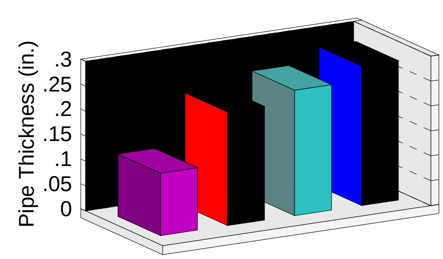
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.280** in.
Minimum Allowable Thickness: **0.125** in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.017 in. / **High to Low Range:** 0.050 in.
Minimum Theoretical Wall Thickness: 0.201 in.
Pitting Index: 9.3 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.251 in.
Average Pipe Loss: 0.029 in.
Corrosion Rate: 0.9 Mils Per Year
Percent of Allowable Pipe Loss: 18.4 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

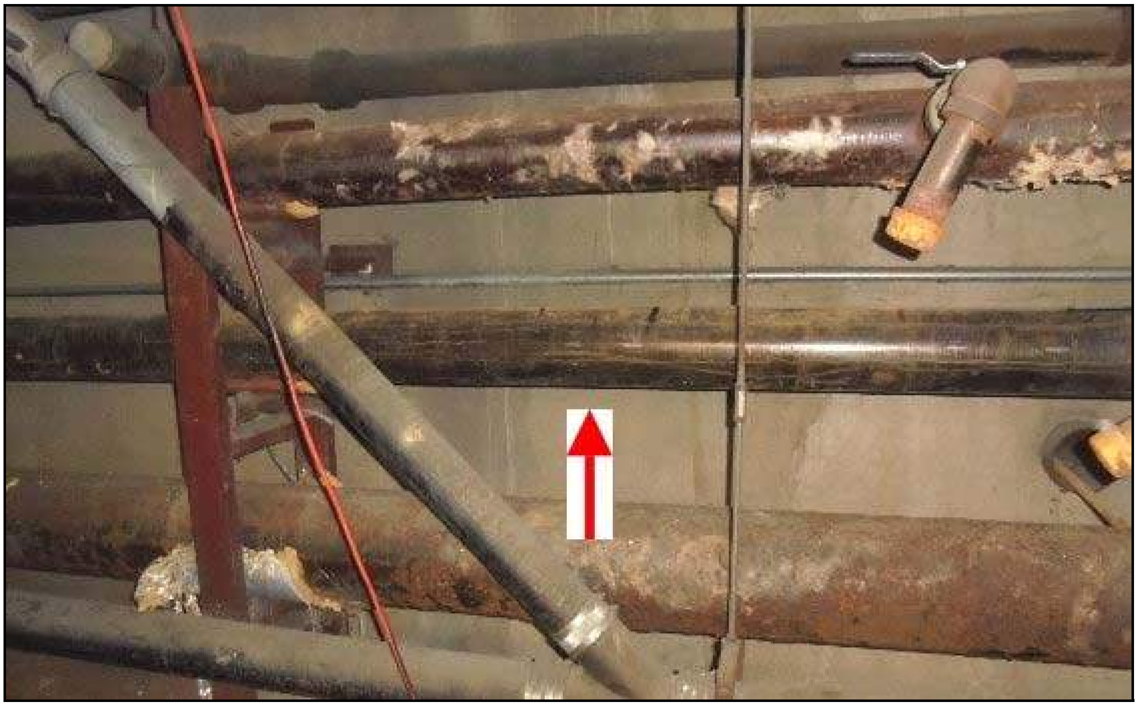
Minimum Thickness: 0.228 in.
Maximum Pipe Loss: 0.052 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 33.5 %
Remaining Pipe Life: 62.6 Years
Estimated Retirement **July 2079**

Testing Indicates: Pipe Condition Very Good

Comments: Testing shows similar results at this example of pipe. We still measure higher than normal internal pitting activity for a closed hot water system. Very long service life remains.

Location No: **37**

Photo File #: phl-1-27.jpg
Detail: Pipe Location / Condition
Orientation: Side View



Pipe Identification and Operating Conditions

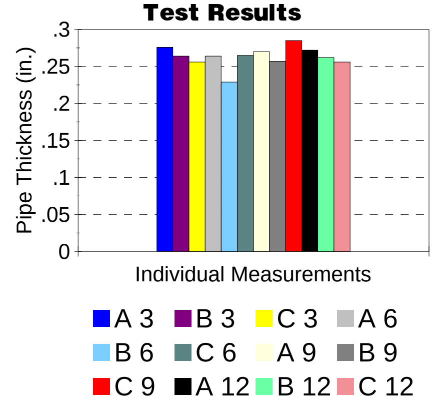
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-07
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 2-4 ft. after 5th pipe support.

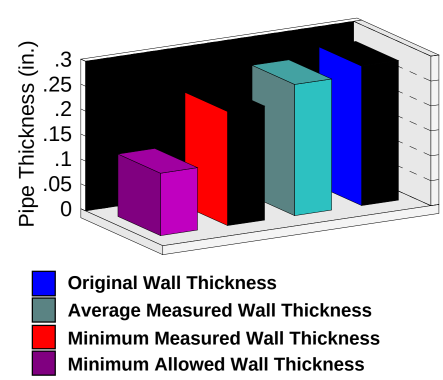
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.014 in. / **High to Low Range:** 0.056 in.
Minimum Theoretical Wall Thickness: 0.222 in.
Pitting Index: 12.9% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.263 in.
Average Pipe Loss: 0.017 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 11.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

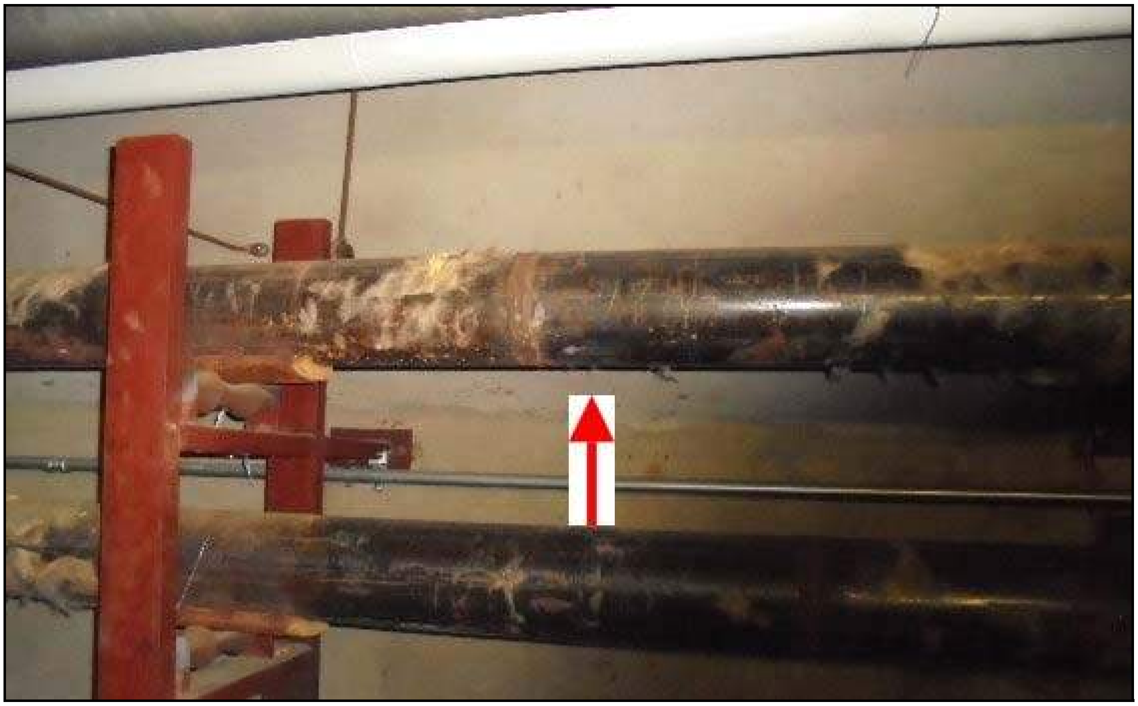
Minimum Thickness: 0.229 in.
Maximum Pipe Loss: 0.051 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 32.9 %
Remaining Pipe Life: 64.4 Years
Estimated Retirement **May 2081**

Testing Indicates: Pipe Condition Very Good

Comments: We produce very similar results at this example of pipe. Testing shows higher than normal corrosion activity but still very long estimated service life available.

Location No: 38

Photo File #: phl-1-42.jpg
Detail: Pipe Location / Condition
Orientation: Side View



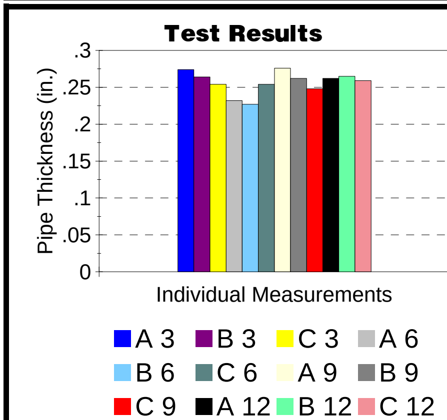
Pipe Identification and Operating Conditions

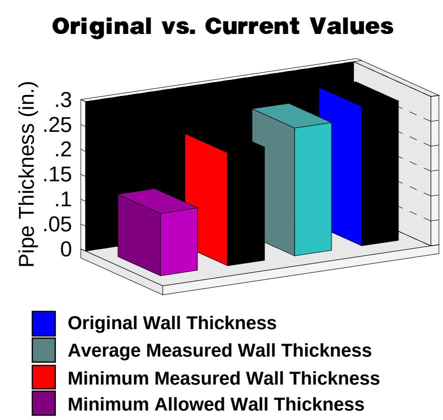
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-09
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 1-3 ft. after 7th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.049 in.
Minimum Theoretical Wall Thickness: 0.212 in.
Pitting Index: 11.5% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.256 in.
Average Pipe Loss: 0.024 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 15.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.227 in.
Maximum Pipe Loss: 0.053 in.
Corrosion Rate: 1.7 Mils Per Year
Percent of Allowable Pipe Loss: 34.2 %
Remaining Pipe Life: 60.8 Years
Estimated Retirement **October 2077**

Testing Indicates: Pipe Condition Very Good

Comments: Testing shows another example of higher than normal corrosion and pitting activity for a closed hot water system. Results are still favorable, with very long service life remaining.

Location No: 39

Photo File #: phl-1-43.jpg
Detail: Pipe Location / Condition
Orientation: Side View

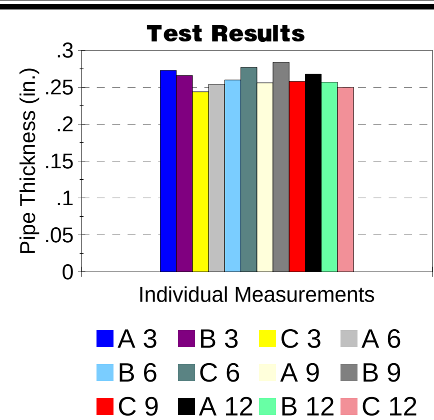
Pipe Identification and Operating Conditions

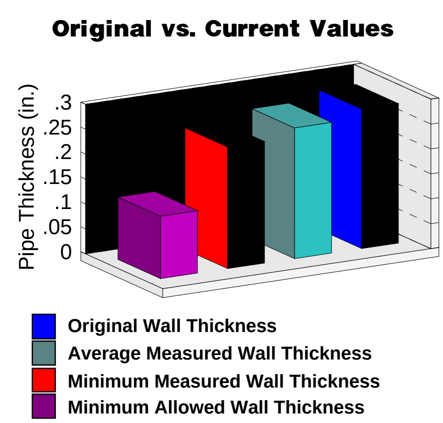
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 55 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-10
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 1-3 ft. after 7th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.037)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.040 in.
Minimum Theoretical Wall Thickness: 0.227 in.
Pitting Index: 7.0 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.262 in.
Average Pipe Loss: 0.018 in.
Corrosion Rate: 0.6 Mils Per Year
Percent of Allowable Pipe Loss: 11.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.244 in.
Maximum Pipe Loss: 0.036 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 23.2 %
Remaining Pipe Life: 104.5 Years
Estimated Retirement **May 2121**

Testing Indicates: Pipe Condition Excellent

Comments: Testing at this location shows very favorable results more in line with what would be expected for a closed hot water system. Wall thickness is high and more uniform. Extremely long service life remains.

Location No: 40

Photo File #: phl-1-64.jpg
Detail: Pipe Location / Condition
Orientation: Side View

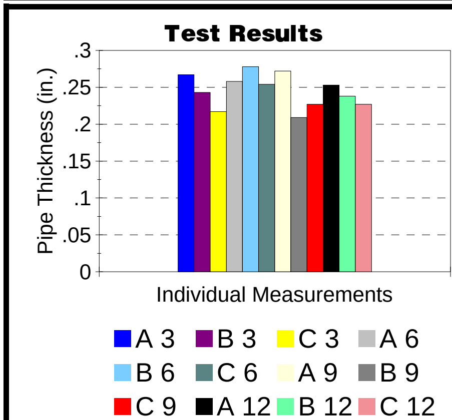
Pipe Identification and Operating Conditions

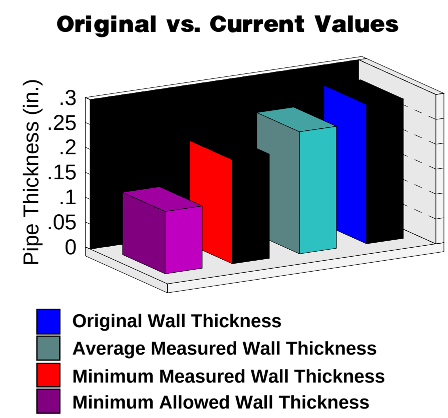
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-11
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 1-3 ft. after 9th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.022 in. / **High to Low Range:** 0.069 in.
Minimum Theoretical Wall Thickness: 0.179 in.
Pitting Index: 14.8% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.245 in.
Average Pipe Loss: 0.035 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 22.4 %
Remaining Pipe Life: 109.4 Years
Estimated Retirement **April 2126**

Worst Case Scenario

Minimum Thickness: 0.209 in.
Maximum Pipe Loss: 0.071 in.
Corrosion Rate: 2.2 Mils Per Year
Percent of Allowable Pipe Loss: 45.8 %
Remaining Pipe Life: 37.4 Years
Estimated Retirement **May 2054**

Testing Indicates: Pipe Condition Good

Comments: Deeper pitting is identified in this example, and is illustrated by the wide variations at the top right bargraph. Long service life remains.

Location No: 41

Photo File #: phl-1-65.jpg
Detail: Pipe Location / Condition
Orientation: Side View

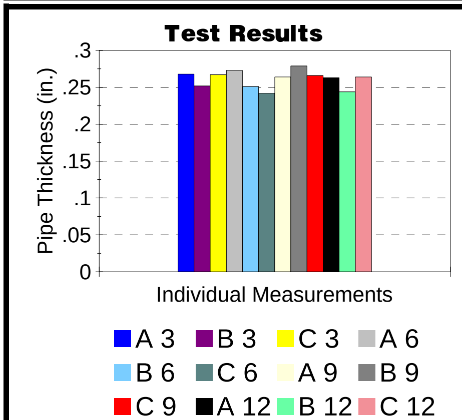
Pipe Identification and Operating Conditions

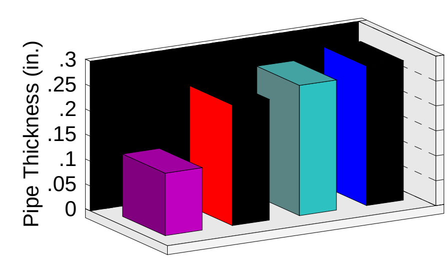
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-12
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 1-3 ft. after 9th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.037 in.
Minimum Theoretical Wall Thickness: 0.227 in.
Pitting Index: 7.3 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.261 in.
Average Pipe Loss: 0.019 in.
Corrosion Rate: 0.6 Mils Per Year
Percent of Allowable Pipe Loss: 12.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.242 in.
Maximum Pipe Loss: 0.038 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 24.5 %
Remaining Pipe Life: 97.3 Years
Estimated Retirement **March 2114**

Testing Indicates: Pipe Condition Excellent

Comments: We again identify much more favorable results at the return side pipe, which is similar to other return piping examples. Testing shows high average wall thickness and extremely long service life available.

Location No: 42

Photo File #: phl-1-70.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

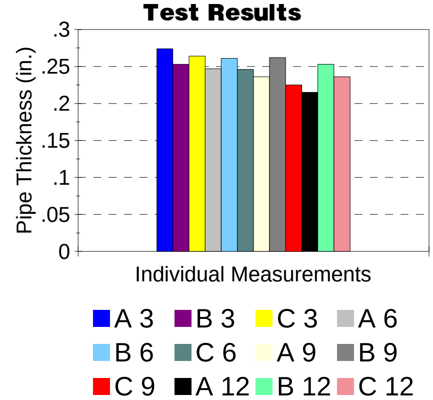
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-13
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located between 11th pipe support and elbow to expansion loop.

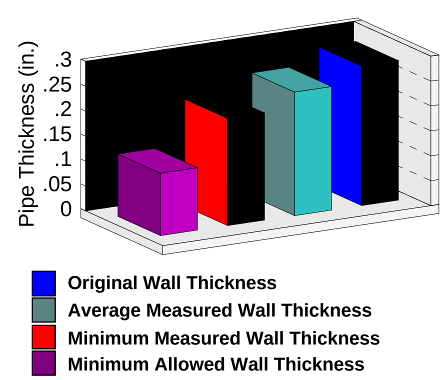
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.280** in.
Minimum Allowable Thickness: **0.125** in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.017 in. / **High to Low Range:** 0.059 in.
Minimum Theoretical Wall Thickness: 0.196 in.
Pitting Index: 13.2% - Significant Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: **0.248** in.
Average Pipe Loss: 0.032 in.
Corrosion Rate: 1.0 Mils Per Year
Percent of Allowable Pipe Loss: 20.9 %
Remaining Pipe Life: 119.9 Years
Estimated Retirement **October 2136**

Worst Case Scenario

Minimum Thickness: **0.215** in.
Maximum Pipe Loss: 0.065 in.
Corrosion Rate: 2.1 Mils Per Year
Percent of Allowable Pipe Loss: 41.9 %
Remaining Pipe Life: 43.8 Years
Estimated Retirement **September 2060**

Testing Indicates: Pipe Condition Good

Comments: Testing shows moderate corrosion and again higher than normal pitting activity. Average wall thickness is high, with very long service life remaining.

Location No: 43

Photo File #: phl-1-71.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

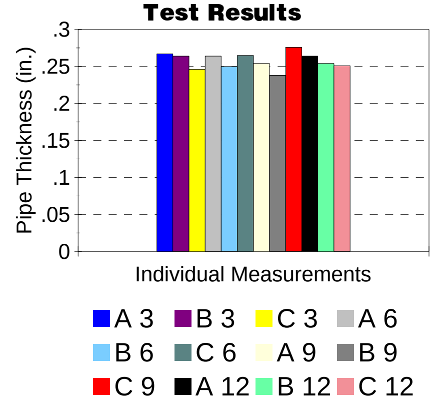
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-14
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located between 11th pipe support and elbow to expansion loop.

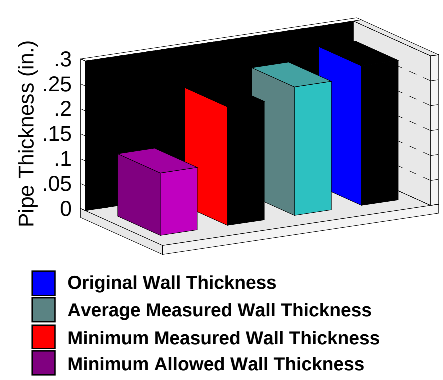
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.038 in.
Minimum Theoretical Wall Thickness: 0.226 in.
Pitting Index: 7.7 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.258 in.
Average Pipe Loss: 0.022 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 14.4 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.238 in.
Maximum Pipe Loss: 0.042 in.
Corrosion Rate: 1.3 Mils Per Year
Percent of Allowable Pipe Loss: 27.1 %
Remaining Pipe Life: 85.0 Years
Estimated Retirement **December 2101**

Testing Indicates: Pipe Condition Excellent

Comments: Testing at this return line again shows noticeably better results. Average wall thicknesses high. Extremely long service life remains.

Location No: 44

Photo File #: phl-1-74.jpg
Detail: Pipe Location / Condition
Orientation: Side View

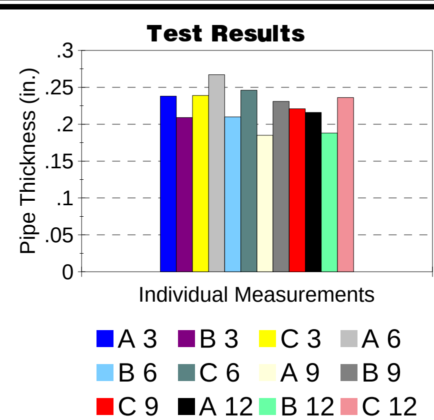
Pipe Identification and Operating Conditions

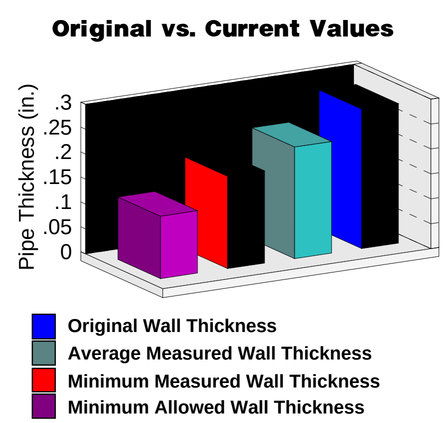
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-15
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located at spool piece after 13th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.038)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.024 in. / **High to Low Range:** 0.082 in.
Minimum Theoretical Wall Thickness: 0.152 in.
Pitting Index: 17.3% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.224 in.
Average Pipe Loss: 0.056 in.
Corrosion Rate: 1.8 Mils Per Year
Percent of Allowable Pipe Loss: 36.2 %
Remaining Pipe Life: 55.6 Years
Estimated Retirement **July 2072**

Worst Case Scenario

Minimum Thickness: 0.185 in.
Maximum Pipe Loss: 0.095 in.
Corrosion Rate: 3.0 Mils Per Year
Percent of Allowable Pipe Loss: 61.3 %
Remaining Pipe Life: 20.0 Years
Estimated Retirement **December 2036**

Testing Indicates: Pipe Condition Satisfactory

Comments: Testing at the supply side pipe again shows noticeably higher corrosion and pitting activity. This section of pipe has now lost 61% of its allowable wall thickness. Long service life remains.

Location No: 45

Photo File #: phl-1-75.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

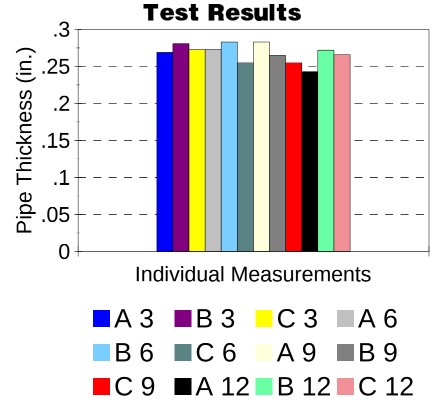
Service: Hot Water Heating
Nominal Pipe Size: 6 in.
Actual Pipe Size: 6.63 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-6-16
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 1-3 ft. after 13th pipe support.

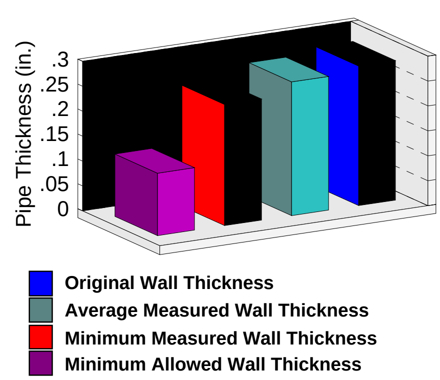
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.280 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.040 in.
Minimum Theoretical Wall Thickness: 0.231 in.
Pitting Index: 9.4 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.268 in.
Average Pipe Loss: 0.012 in.
Corrosion Rate: 0.4 Mils Per Year
Percent of Allowable Pipe Loss: 7.6 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

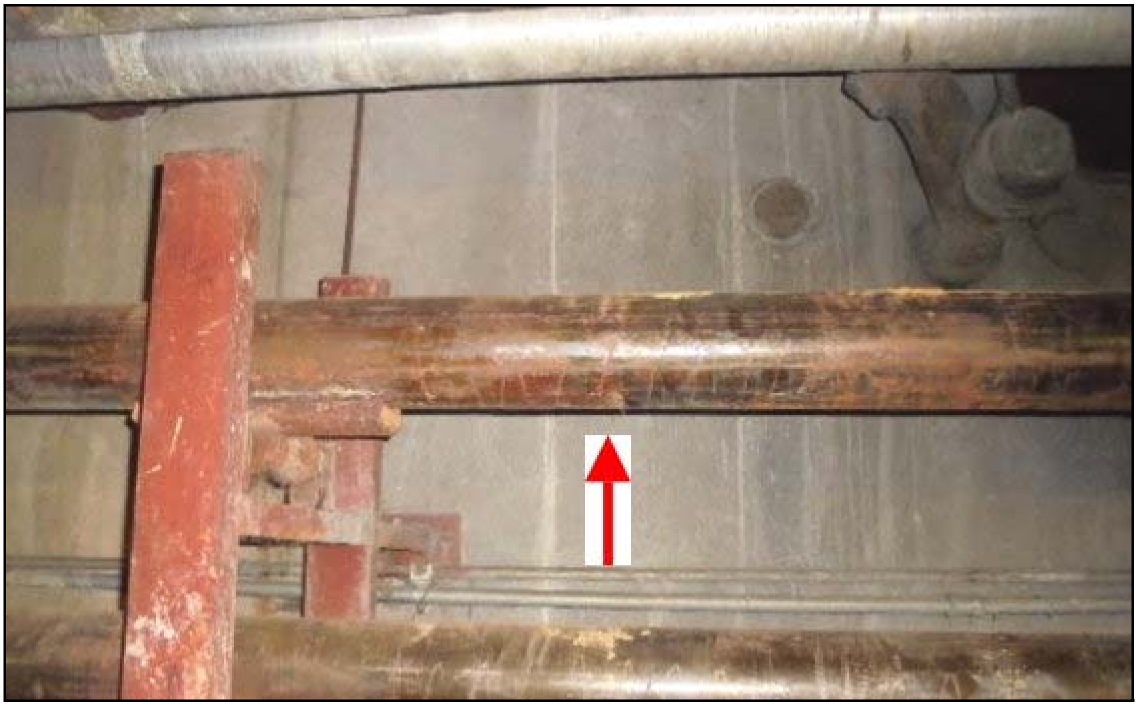
Minimum Thickness: 0.243 in.
Maximum Pipe Loss: 0.037 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 23.9 %
Remaining Pipe Life: 100.8 Years
Estimated Retirement **September 2117**

Testing Indicates: Pipe Condition Excellent

Comments: Testing at the return side pipe again shows dramatically higher and more uniform wall thickness due to lower corrosion activity; with no obvious explanation to such occurrence. Extremely long service life remains.

Location No: 46

Photo File #: phl-1-81.jpg
Detail: Pipe Location / Condition
Orientation: Side View



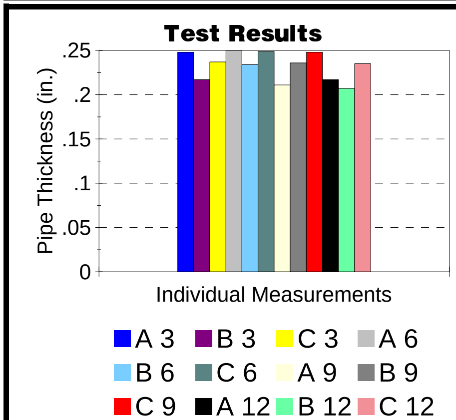
Pipe Identification and Operating Conditions

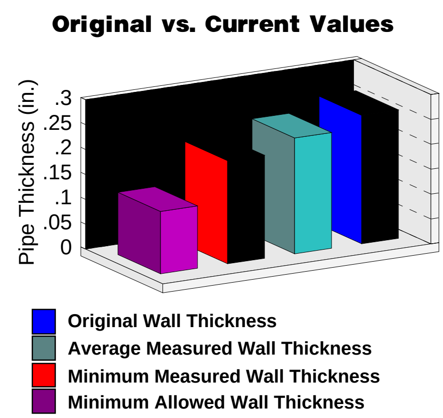
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-17
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 1-3 ft. after 16th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.016 in. / **High to Low Range:** 0.043 in.
Minimum Theoretical Wall Thickness: 0.185 in.
Pitting Index: 10.9% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.232 in.
Average Pipe Loss: 0.026 in.
Corrosion Rate: 0.8 Mils Per Year
Percent of Allowable Pipe Loss: 19.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.207 in.
Maximum Pipe Loss: 0.051 in.
Corrosion Rate: 1.6 Mils Per Year
Percent of Allowable Pipe Loss: 38.3 %
Remaining Pipe Life: 50.8 Years
Estimated Retirement **October 2067**

Testing Indicates: Pipe Condition Very Good

Comments: Testing shows moderate corrosion activity and higher pitting. High pitting activity is shown by the variations in the top right bargraph. Very long service life remains.

Location No: 47

Photo File #: phl-1-82.jpg
Detail: Pipe Location / Condition
Orientation: Side View

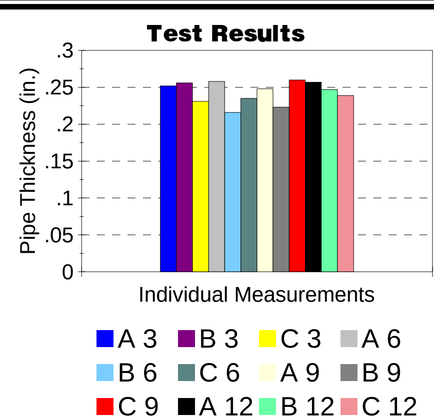
Pipe Identification and Operating Conditions

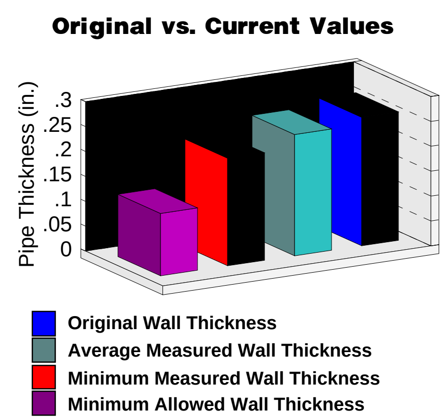
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-18
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 1-3 ft. after 16th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.034)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.015 in. / **High to Low Range:** 0.044 in.
Minimum Theoretical Wall Thickness: 0.200 in.
Pitting Index: 11.3% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.244 in.
Average Pipe Loss: 0.014 in.
Corrosion Rate: 0.5 Mils Per Year
Percent of Allowable Pipe Loss: 10.9 %
Remaining Pipe Life: 125.0 Years

Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.216 in.
Maximum Pipe Loss: 0.042 in.
Corrosion Rate: 1.3 Mils Per Year
Percent of Allowable Pipe Loss: 31.6 %
Remaining Pipe Life: 68.5 Years

Estimated Retirement **June 2085**

Testing Indicates: Pipe Condition Very Good

Comments: We again measure lower corrosion activity at this example of return pipe. Average wall thickness is not far below new schedule 40 specifications. Very long service life remains.

Location No: 48

Photo File #: phl-1-118.jpg
Detail: Pipe Location / Condition
Orientation: Side View

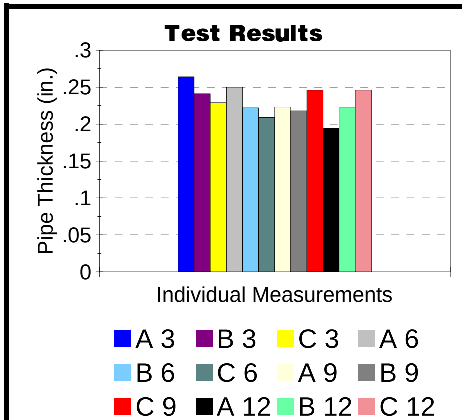
Pipe Identification and Operating Conditions

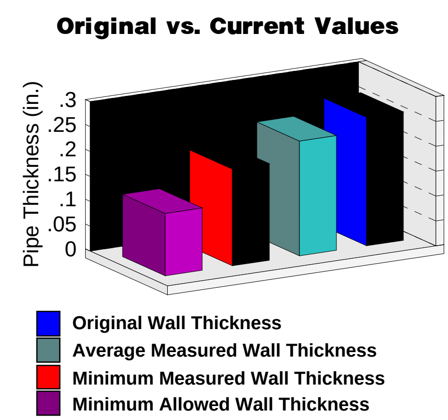
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-21
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 1-3 ft. after 19th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.020 in. / **High to Low Range:** 0.070 in.
Minimum Theoretical Wall Thickness: 0.171 in.
Pitting Index: 15.8% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.230 in.
Average Pipe Loss: 0.028 in.
Corrosion Rate: 0.9 Mils Per Year
Percent of Allowable Pipe Loss: 20.8 %
Remaining Pipe Life: 120.3 Years
Estimated Retirement **March 2137**

Worst Case Scenario

Minimum Thickness: 0.194 in.
Maximum Pipe Loss: 0.064 in.
Corrosion Rate: 2.0 Mils Per Year
Percent of Allowable Pipe Loss: 48.1 %
Remaining Pipe Life: 34.1 Years
Estimated Retirement **January 2051**

Testing Indicates: Pipe Condition Good

Comments: Testing at another example of supply side pipe identifies similar higher corrosion and pitting activity to other examples of supply pipe. Long service life remains.

Location No: 49

Photo File #: phl-1-119.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

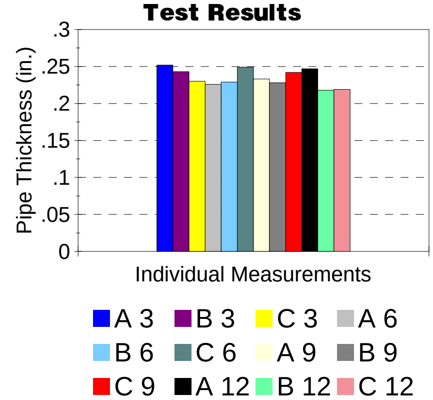
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-22
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 1-3 ft. after 19th pipe support.

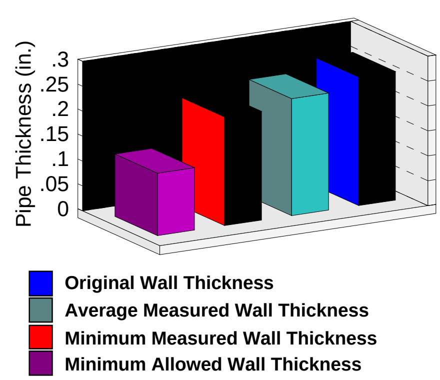
Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.034)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.012 in. / **High to Low Range:** 0.034 in.
Minimum Theoretical Wall Thickness: 0.200 in.
Pitting Index: 7.1 % - Moderate Pitting Activity
Notes: None

Graphical Summary

Test Results



Original vs. Current Values



Average Case Scenario

Average Thickness: 0.235 in.
Average Pipe Loss: 0.023 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 17.5 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.218 in.
Maximum Pipe Loss: 0.040 in.
Corrosion Rate: 1.3 Mils Per Year
Percent of Allowable Pipe Loss: 30.1 %
Remaining Pipe Life: 73.5 Years
Estimated Retirement **June 2090**

Testing Indicates: Pipe Condition Very Good

Comments: We measure noticeably lower corrosion and pitting activity at this example of pipe resulting in a much more favorable service life estimate. Extremely long service life remains.

Location No: **50**

Photo File #: phl-1-129.jpg
Detail: Pipe Location / Condition
Orientation: Side View

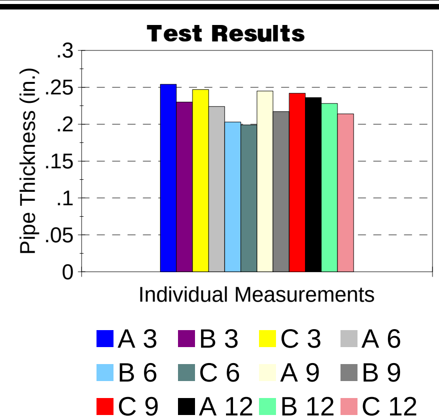
Pipe Identification and Operating Conditions

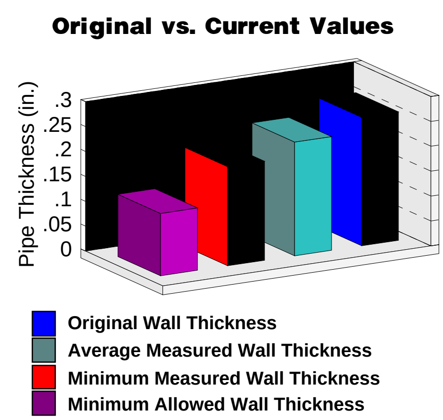
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-23
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 2-4 ft. after 23rd pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.018 in. / **High to Low Range:** 0.055 in.
Minimum Theoretical Wall Thickness: 0.176 in.
Pitting Index: 12.8% - Significant Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.228 in.
Average Pipe Loss: 0.030 in.
Corrosion Rate: 0.9 Mils Per Year
Percent of Allowable Pipe Loss: 22.4 %
Remaining Pipe Life: 109.7 Years
Estimated Retirement **August 2126**

Worst Case Scenario

Minimum Thickness: 0.199 in.
Maximum Pipe Loss: 0.059 in.
Corrosion Rate: 1.9 Mils Per Year
Percent of Allowable Pipe Loss: 44.4 %
Remaining Pipe Life: 39.6 Years
Estimated Retirement **August 2056**

Testing Indicates: Pipe Condition Good

Comments: Testing at the supply line again shows higher pitting activity. Corrosion activity would be considered moderate. Long service life remains.

Location No: 51

Photo File #: phl-1-130.jpg
Detail: Pipe Location / Condition
Orientation: Side View

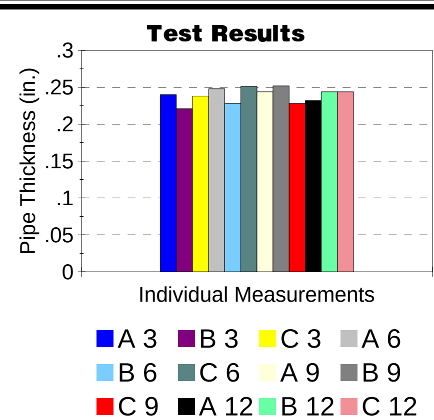
Pipe Identification and Operating Conditions

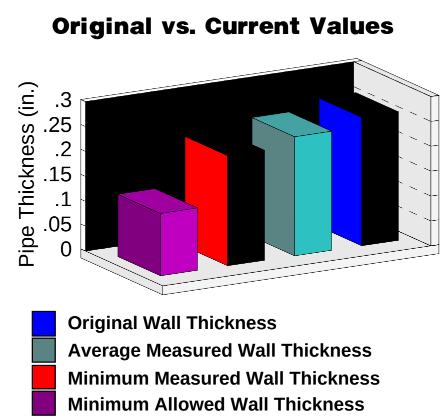
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-24
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 2-4 ft. after 23rd pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.034)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.010 in. / **High to Low Range:** 0.031 in.
Minimum Theoretical Wall Thickness: 0.209 in.
Pitting Index: 7.6 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.239 in.
Average Pipe Loss: 0.019 in.
Corrosion Rate: 0.6 Mils Per Year
Percent of Allowable Pipe Loss: 14.2 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

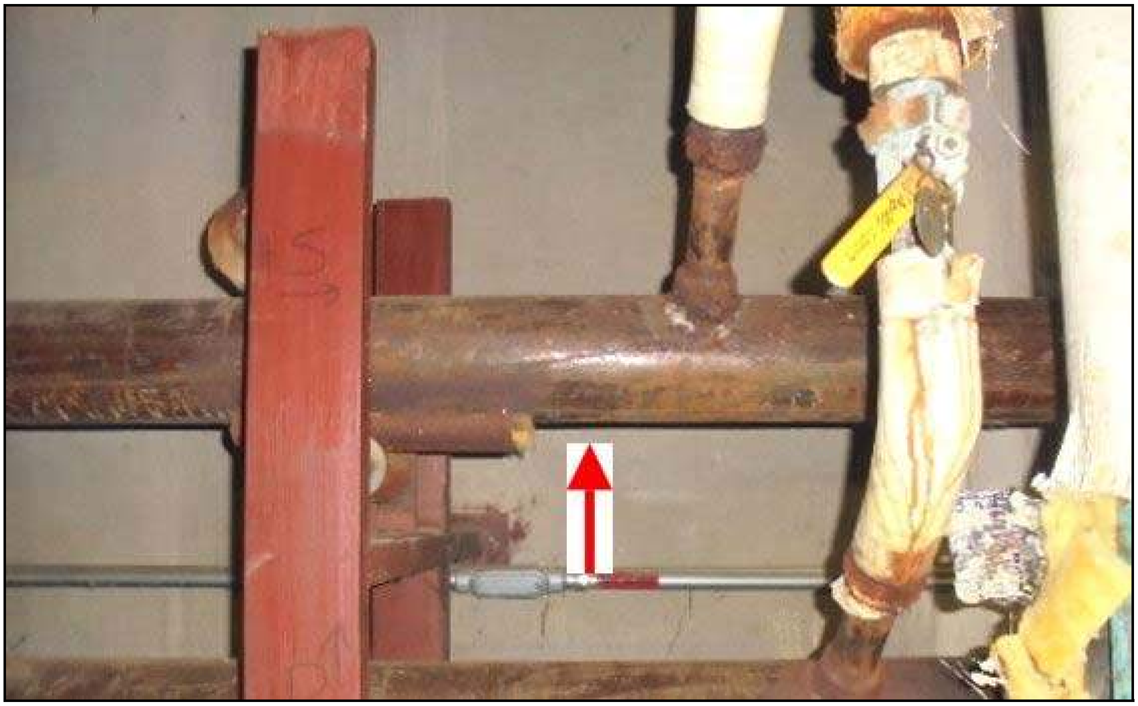
Minimum Thickness: 0.221 in.
Maximum Pipe Loss: 0.037 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 27.8 %
Remaining Pipe Life: 82.0 Years
Estimated Retirement **December 2098**

Testing Indicates: Pipe Condition Excellent

Comments: We measure much higher and more uniform wall thickness at this example of return line. Corrosion activity is lower and more uniform. Extremely long service life remains.

Location No: 52

Photo File #: phl-1-133.jpg
Detail: Pipe Location / Condition
Orientation: Side View



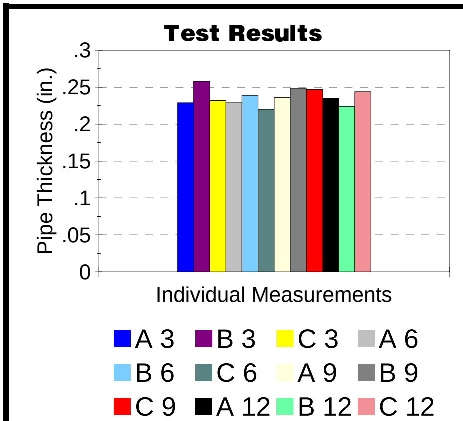
Pipe Identification and Operating Conditions

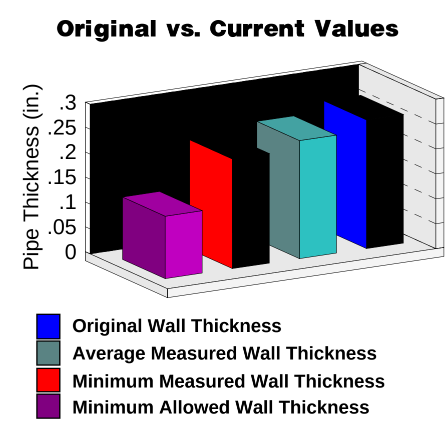
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-25
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main supply line. Test points located 1-2 ft. after 27th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.036)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.011 in. / **High to Low Range:** 0.038 in.
Minimum Theoretical Wall Thickness: 0.204 in.
Pitting Index: 7.1 % - Moderate Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.237 in.
Average Pipe Loss: 0.021 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 16.0 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

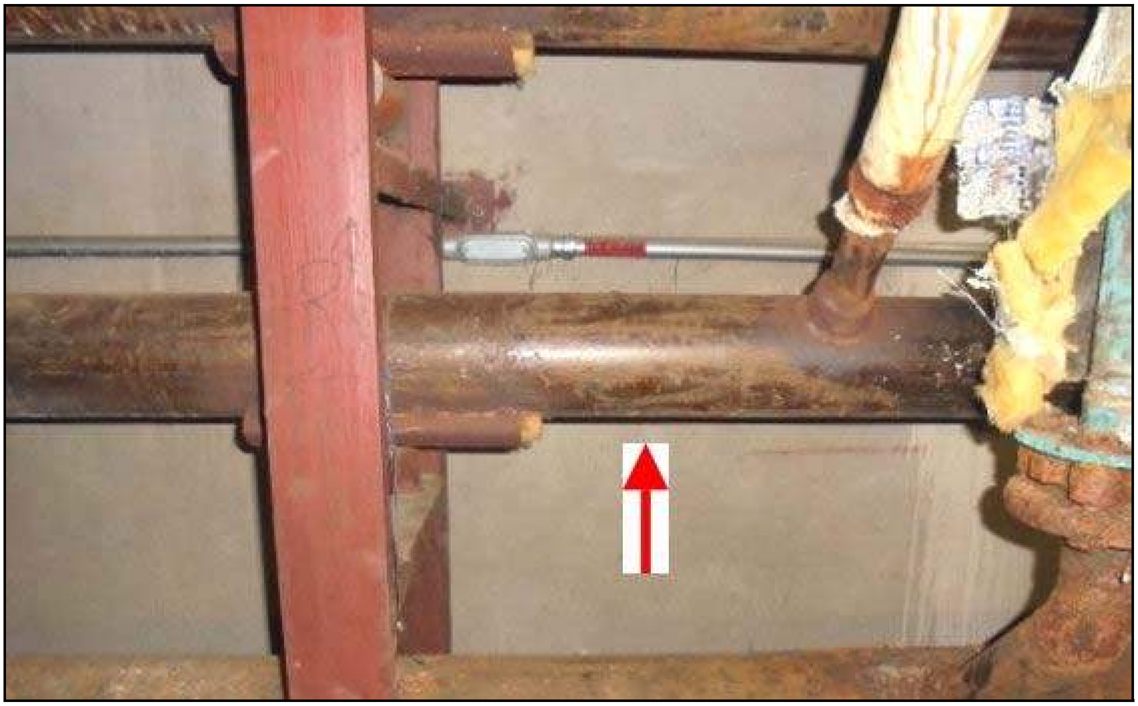
Minimum Thickness: 0.220 in.
Maximum Pipe Loss: 0.038 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 28.6 %
Remaining Pipe Life: 79.0 Years
Estimated Retirement **December 2095**

Testing Indicates: Pipe Condition Excellent

Comments: Testing at this supply side example of pipe shows higher and more uniform wall thickness. Corrosion activity would be still considered moderate. Extremely long service life remains.

Location No: 53

Photo File #: phl-1-134.jpg
Detail: Pipe Location / Condition
Orientation: Side View



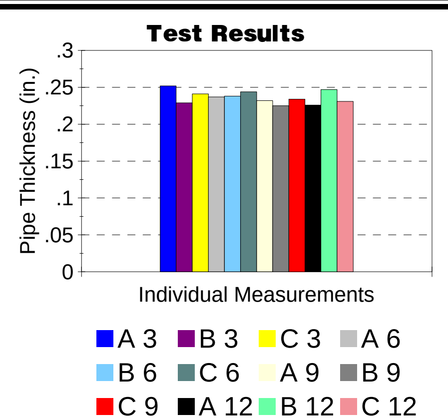
Pipe Identification and Operating Conditions

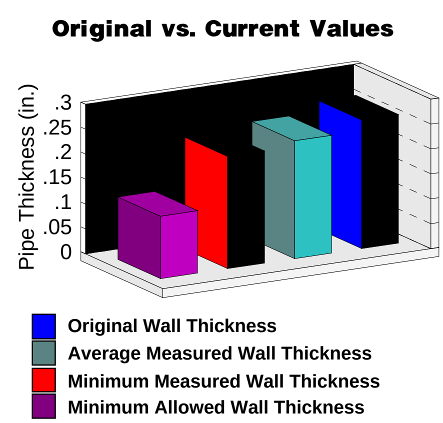
Service: Hot Water Heating
Nominal Pipe Size: 5 in.
Actual Pipe Size: 5.56 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Welded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-5-26
Site Drawing Number: n/a
Depth Allowance: 0.000 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating main return line. Test points located 1-2 ft. after 27th pipe support.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.258 in.
Minimum Allowable Thickness: 0.125 in. (0.034)
Minimum Thickness Based Upon: Default Minimum Value
Standard Deviation: 0.008 in. / **High to Low Range:** 0.027 in.
Minimum Theoretical Wall Thickness: 0.211 in.
Pitting Index: 4.8 % - Acceptable Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.236 in.
Average Pipe Loss: 0.022 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 16.3 %
Remaining Pipe Life: 125.0 Years
Estimated Retirement **November 2141**

Worst Case Scenario

Minimum Thickness: 0.225 in.
Maximum Pipe Loss: 0.033 in.
Corrosion Rate: 1.0 Mils Per Year
Percent of Allowable Pipe Loss: 24.8 %
Remaining Pipe Life: 95.8 Years
Estimated Retirement **September 2112**

Testing Indicates: Pipe Condition Excellent

Comments: We produce more favorable results again at the return side pipe where wall thickness is higher and more uniform. Extremely long service life remains.

Location No: 54

Photo File #: phl-1-13.jpg
Detail: Pipe Location / Condition
Orientation: Side View

Pipe Identification and Operating Conditions

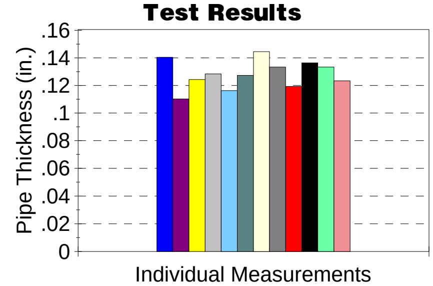
Service: Hot Water Heating
Nominal Pipe Size: 2 in.
Actual Pipe Size: 2.38 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Threaded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-HWH-2-03
Site Drawing Number: n/a
Depth Allowance: 0.073 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 1st hot water heating take-off from main supply line, at 1st take-off. Test points located between weldolet and union.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.154 in.
Minimum Allowable Thickness: 0.095 in. (0.103)
Minimum Thickness Based Upon:
Standard Deviation: 0.010 in. / **High to Low Range:** 0.034 in.
Minimum Theoretical Wall Thickness: 0.098 in.
Pitting Index: 13.9% - Significant Pitting Activity
Notes: Pipe exists 37 mils from the threads, see Addendum.

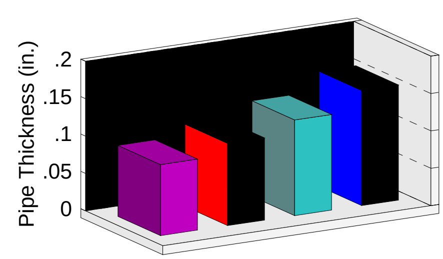
Graphical Summary

Test Results



A 3 B 3 C 3 A 6
B 6 C 6 A 9 B 9
C 9 A 12 B 12 C 12

Original vs. Current Values



Original Wall Thickness
Average Measured Wall Thickness
Minimum Measured Wall Thickness
Minimum Allowed Wall Thickness

Average Case Scenario

Average Thickness: 0.128 in.
Average Pipe Loss: 0.026 in.
Corrosion Rate: 0.8 Mils Per Year
Percent of Allowable Pipe Loss: 44.5 %
Remaining Pipe Life: 39.4 Years
Estimated Retirement **May 2056**

Worst Case Scenario

Minimum Thickness: 0.110 in.
Maximum Pipe Loss: 0.044 in.
Corrosion Rate: 1.4 Mils Per Year
Percent of Allowable Pipe Loss: 74.6 %
Remaining Pipe Life: 10.8 Years
Estimated Retirement **October 2027**

Testing Indicates: Pipe Condition Satisfactory

Comments: Testing at the small diameter take off-line shows the same higher than normal corrosion activity. Acting against small diameter threaded pipe, far less service life remains.

Location No: 55

Photo File #: phl-1-30.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

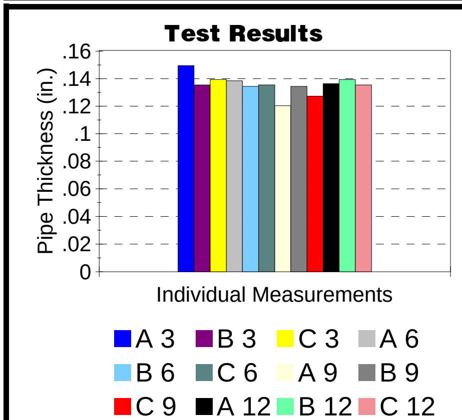
Pipe Identification and Operating Conditions

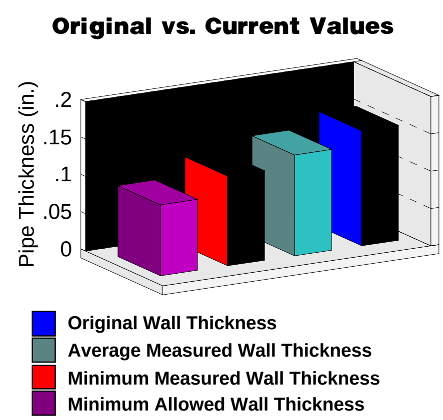
Service: Hot Water Heating
Nominal Pipe Size: 2 in.
Actual Pipe Size: 2.38 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Threaded
Flow: futur
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Horizontal
Test Site I.D.: T-HWH-2-08
Site Drawing Number: n/a
Depth Allowance: 0.073 in.
Test Pattern: Bottom & Lower Sides

Location - Terminal B Tunnel: Hot water heating future take-off, from main supply line. Test points located between weldolet at main and valve.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.154 in.
Minimum Allowable Thickness: 0.095 in. (0.103)
Minimum Thickness Based Upon:
Standard Deviation: 0.007 in. / **High to Low Range:** 0.029 in.
Minimum Theoretical Wall Thickness: 0.114 in.
Pitting Index: 11.2% - Significant Pitting Activity
Notes: Pipe exists 47 mils from the threads, see Addendum.

Graphical Summary





Average Case Scenario

Average Thickness: 0.135 in.
Average Pipe Loss: 0.019 in.
Corrosion Rate: 0.6 Mils Per Year
Percent of Allowable Pipe Loss: 32.1 %
Remaining Pipe Life: 67.0 Years
Estimated Retirement **December 2083**

Worst Case Scenario

Minimum Thickness: 0.120 in.
Maximum Pipe Loss: 0.034 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 57.6 %
Remaining Pipe Life: 23.2 Years
Estimated Retirement **March 2040**

Testing Indicates: Pipe Condition Satisfactory

Comments: Testing at this example pipe shows more favorable results. We measure higher average wall thickness not far below new schedule 40 specifications. Long service life remains.

Location No: 56

Photo File #: phl-1-91.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

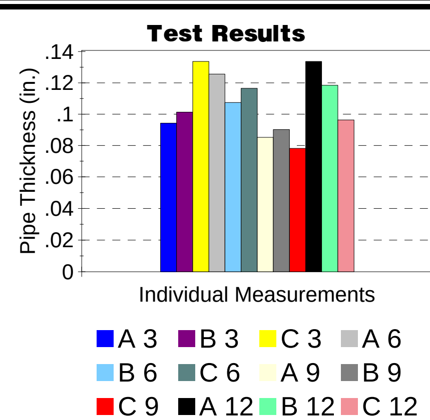
Pipe Identification and Operating Conditions

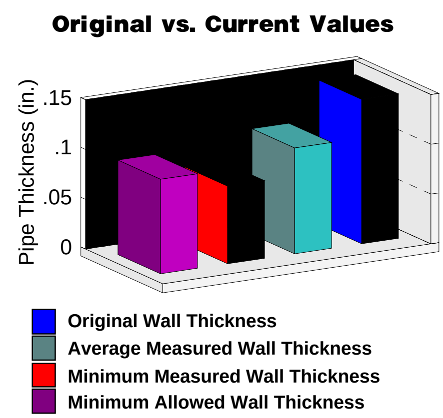
Service: Hot Water Heating
Nominal Pipe Size: 1-1/2 in.
Actual Pipe Size: 1.90 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Threaded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-HWH-1-1/2-19
Site Drawing Number: n/a
Depth Allowance: 0.073 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 5th hot water heating take-off from main supply line, after 16th pipe support. Test points located between weldolet and union.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.145 in.
Minimum Allowable Thickness: 0.095 in. (0.102)
Minimum Thickness Based Upon:
Standard Deviation: 0.019 in. / **High to Low Range:** 0.055 in.
Minimum Theoretical Wall Thickness: 0.050 in.
Pitting Index: 26.6% - High Pitting Activity
Notes: None

Graphical Summary





Average Case Scenario

Average Thickness: 0.106 in.
Average Pipe Loss: 0.039 in.
Corrosion Rate: 1.2 Mils Per Year
Percent of Allowable Pipe Loss: 77.3 %
Remaining Pipe Life: 9.3 Years
Estimated Retirement **April 2026**

Worst Case Scenario

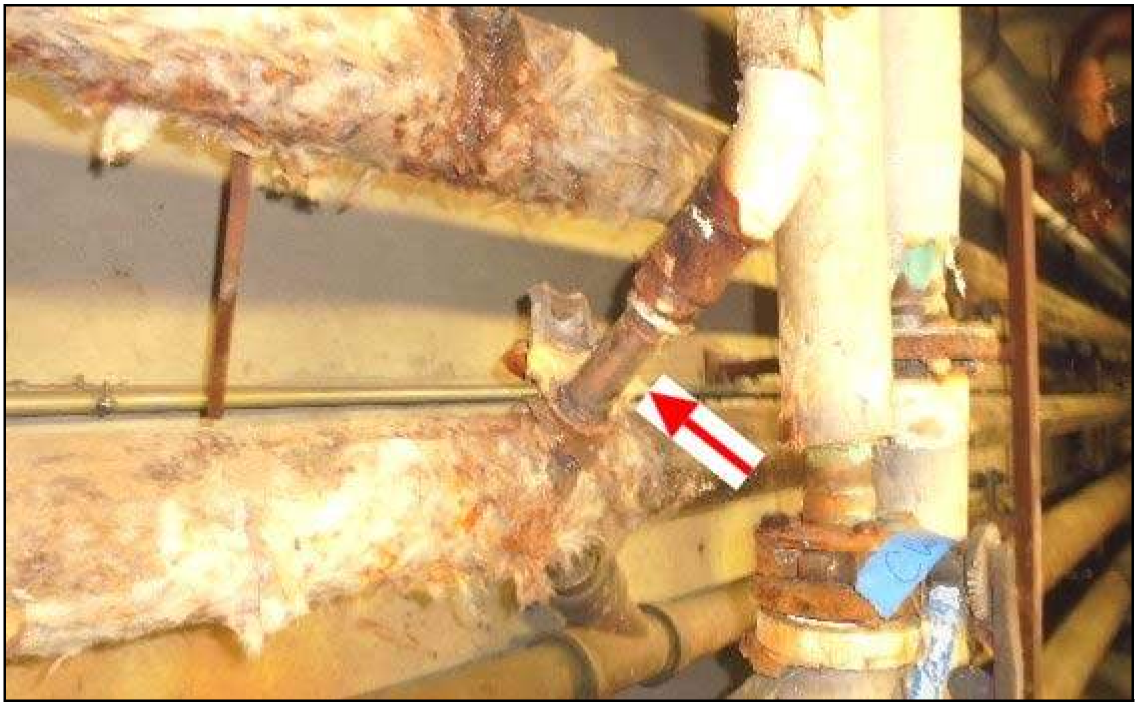
Minimum Thickness: 0.078 in.
Maximum Pipe Loss: 0.067 in.
Corrosion Rate: 2.1 Mils Per Year
Percent of Allowable Pipe Loss: 100.0 %
Remaining Pipe Life: 0.0 Years
Estimated Retirement **December 2016**

Testing Indicates: Leak Now Exists

Comments: Testing shows high corrosion and severe pitting activity at this example of pipe. We measure extremely low wall thickness now approaching the thread cut. No further service life remains.

Location No: 57

Photo File #: phl-1-93.jpg
Detail: Pipe Location / Condition
Orientation: Side View



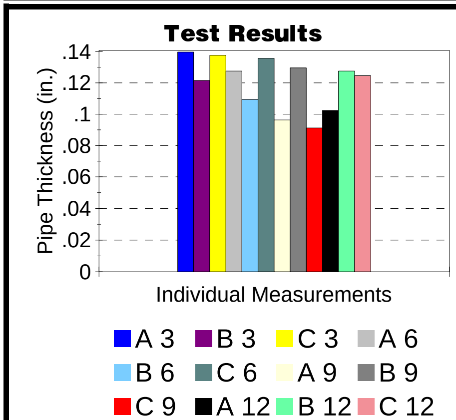
Pipe Identification and Operating Conditions

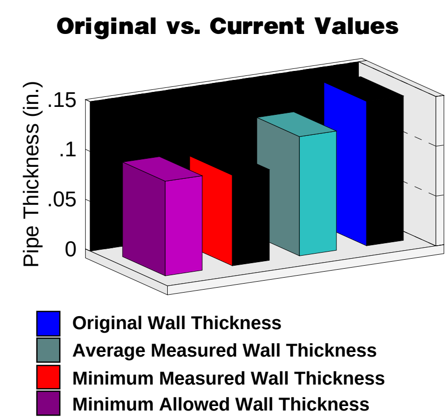
Service: Hot Water Heating
Nominal Pipe Size: 1-1/2 in.
Actual Pipe Size: 1.90 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Threaded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-HWH-1-1/2-20
Site Drawing Number: n/a
Depth Allowance: 0.073 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 5th hot water heating take-off from main return line, after 16th pipe support. Test points located between weldolet and union.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: **0.145** in.
Minimum Allowable Thickness: **0.095** in. (0.101)
Minimum Thickness Based Upon:
Standard Deviation: 0.016 in. / **High to Low Range:** 0.048 in.
Minimum Theoretical Wall Thickness: 0.071 in.
Pitting Index: 24.0% - High Pitting Activity
Notes: Pipe exists 18 mils from the threads, see Addendum.

Graphical Summary





Average Case Scenario

Average Thickness: **0.120** in.
Average Pipe Loss: 0.025 in.
Corrosion Rate: 0.8 Mils Per Year
Percent of Allowable Pipe Loss: 50.5 %
Remaining Pipe Life: 31.0 Years
Estimated Retirement **December 2047**

Worst Case Scenario

Minimum Thickness: **0.091** in.
Maximum Pipe Loss: 0.054 in.
Corrosion Rate: 1.7 Mils Per Year
Percent of Allowable Pipe Loss: 100.0 %
Remaining Pipe Life: 0.0 Years
Estimated Retirement **December 2016**

Testing Indicates: Pipe Replacement Indicated

Comments: Testing at another take off-line shows high pitting activity and low wall thickness now having reached below minimum standards. No further reliable service life remains.

Location No: 58

Photo File #: phl-1-135.jpg
Detail: Pipe Location / Condition
Orientation: Below Side View

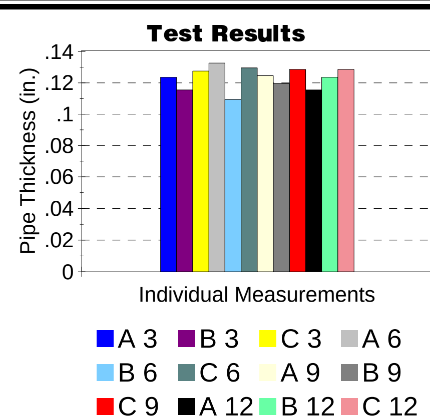
Pipe Identification and Operating Conditions

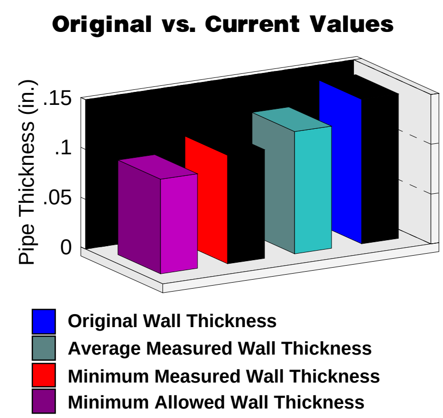
Service: Hot Water Heating
Nominal Pipe Size: 1-1/2 in.
Actual Pipe Size: 1.90 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Threaded
Flow: Supply To Building
Pipe Pressure: 60 PSIG
Temperature: 160 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-HWH-1-1/2-27
Site Drawing Number: n/a
Depth Allowance: 0.073 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 8th hot water heating take-off from main supply line, after 27th pipe support. Test points located between weldolet and union.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.145 in.
Minimum Allowable Thickness: 0.095 in. (0.102)
Minimum Thickness Based Upon:
Standard Deviation: 0.007 in. / **High to Low Range:** 0.023 in.
Minimum Theoretical Wall Thickness: 0.102 in.
Pitting Index: 11.1% - Significant Pitting Activity
Notes: Pipe exists 36 mils from the threads, see Addendum.

Graphical Summary





Average Case Scenario

Average Thickness: 0.123 in.
Average Pipe Loss: 0.022 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 44.7 %
Remaining Pipe Life: 39.1 Years
Estimated Retirement **February 2056**

Worst Case Scenario

Minimum Thickness: 0.109 in.
Maximum Pipe Loss: 0.036 in.
Corrosion Rate: 1.1 Mils Per Year
Percent of Allowable Pipe Loss: 72.0 %
Remaining Pipe Life: 12.3 Years
Estimated Retirement **April 2029**

Testing Indicates: Pipe Condition Satisfactory

Comments: We produce more favorable results at this example of pipe, but also document that only limited service life should be expected.

Location No: 59

Photo File #: phl-1-136.jpg
Detail: Pipe Location / Condition
Orientation: Side View

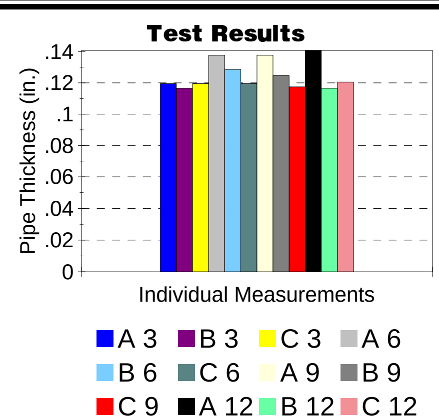
Pipe Identification and Operating Conditions

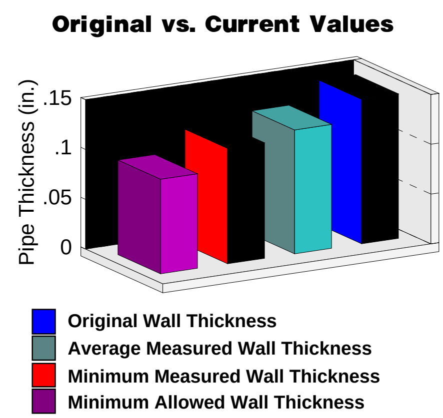
Service: Hot Water Heating
Nominal Pipe Size: 1-1/2 in.
Actual Pipe Size: 1.90 in.
Schedule/Type: Schedule 40
Material: Carbon Steel
Construction: Threaded
Flow: Return To Boiler
Pipe Pressure: 50 PSIG
Temperature: 130 Deg. F.
Pipe Orientation: Diagonal
Test Site I.D.: T-HWH-1-1/2-28
Site Drawing Number: n/a
Depth Allowance: 0.073 in.
Test Pattern: Random Points

Location - Terminal B Tunnel: 8th hot water heating take-off from main return line, after 27th pipe support. Test points located between weldolet and union.

Placed In Service: June 1, 1985
Date of Test: December 30, 2016
Time In Service: 31.6 Years
Original Wall Thickness: 0.145 in.
Minimum Allowable Thickness: 0.095 in. (0.101)
Minimum Thickness Based Upon:
Standard Deviation: 0.009 in. / **High to Low Range:** 0.024 in.
Minimum Theoretical Wall Thickness: 0.098 in.
Pitting Index: 6.7 % - Moderate Pitting Activity
Notes: Pipe exists 43 mils from the threads, see Addendum.

Graphical Summary





Average Case Scenario

Average Thickness: 0.124 in.
Average Pipe Loss: 0.021 in.
Corrosion Rate: 0.7 Mils Per Year
Percent of Allowable Pipe Loss: 41.3 %
Remaining Pipe Life: 44.9 Years
Estimated Retirement **October 2061**

Worst Case Scenario

Minimum Thickness: 0.116 in.
Maximum Pipe Loss: 0.029 in.
Corrosion Rate: 0.9 Mils Per Year
Percent of Allowable Pipe Loss: 58.0 %
Remaining Pipe Life: 22.9 Years
Estimated Retirement **November 2039**

Testing Indicates: Pipe Condition Satisfactory

Comments: Testing at this threaded take off-line shows far more favorable results but still higher than normal pitting activity. Average wall thicknesses high, with long service life remaining.

- SECTION SEVEN -

Conclusions and Recommendations

This ultrasonic testing and analysis report should be viewed as a first step in determining the general condition of the chill water and hot water heating piping systems at the B service tunnel at xxxxxxxxxxxxxxxxx xxxxxxx. Although it is based upon accepted engineering calculations, ASTM pipe specifications, and the latest ultrasonic technology, it is not, in every case, intended to serve as an absolute and conclusive determination of pipe condition.

The purpose of this report summary section is to impart to the reader a thorough and complete knowledge of the condition of the piping addressed in our field investigation equal to our own. Since we do not always have the benefit of personally returning to the test site and reviewing its contents with the reader, we attempt to accomplish the same exchange in writing. This report contains a large volume of new and often interrelated findings and/or relationships requiring a narrative explanation. Reviewing the specific test locations from section four referenced throughout this narrative will likely assist in understanding its content.

This investigation was initiated following an observation of rust covering some areas of the chill water piping. Removing the pipe insulation exposed examples of heavier rust to suggest a potential threat to airport operations. As a result, ultrasonic testing was specified for the chill water piping throughout tunnel B, as well as to the hot water heating pipe.

Our final narration closely follows the sequence of results presented in section four.

Chilled Water - Locations 1 through 31

We identified generally excellent results for the chill water piping in contrast to what had been expected based upon its visual condition. For any form of carbon steel pipe, significantly greater iron oxide rust product is produced from the original steel which has been corroded. A rough estimate is that an approximately 18 times greater volume of less dense iron oxide is created from the corrosion or oxidation of carbon steel. This general rule holds true whether corrosion activity is occurring to the inside or outside of the pipe surface, but with different consequences.

Internal corrosion remains trapped within any piping system unless there is some form of mechanical filtration system and / or regular chemical cleaning to remove it. This rust product migrates and settles in low flow areas to produce significantly higher under deposit corrosion activity, as well as reduces heat transfer efficiency at cooling coils where rust deposition is often the heaviest. Even under low corrosion rates, significant volumes of rust product are created every year, and build up to detrimental levels over decades of operation.

For all chill water piping systems, a potentially significant threat exists to its outer surface due to insulation failure. No steel pipe is ever painted or coated for corrosion protection prior to insulation, and therefore its future condition is solely dependent upon the effectiveness of the insulation material applied. External coverings of plastic or metal are ineffective unless silicone sealed at every joint, which typically they are not. Furthermore, the process of deterioration typically occurs hidden from view until some event such as a leak or wet insulation or crystallization at the surface signals a problem.

Contrary to stated claims, fiberglass insulation provides a relatively weak moisture barrier which easily allows moisture to penetrate and reached the cold metal surface. Condensation is typically worst at the colder supply side pipe, with heaviest deterioration often along the bottom where condensation pools. Worst case conditions can totally destroy a chilled water system after decades of the pipe remaining in water saturated insulation. Outer surface corrosion is typically very random depending upon insulation quality, pipe temperature, insulation thickness, and where breaks in the insulation exist such as at tees and elbows.

In the photographs below we show an example of chill water pipe having a heavier volume of outer surface rust at the bottom due to condensation accumulating in this area. Its condition represents the concern originally expressed for this piping system. At left we show the pipe condition following removal of the insulation. Surface rust would be classified as light to moderate, with some unaffected areas of bare steel still showing. Below right we show the surface rust removed by wire wheel to reveal mild outer pitting to a depth measured by micrometer at 0.035 in. Although an unnecessary and unexpected loss, such pitting is relatively insignificant against 10 in. schedule 40 pipe having an initial wall thickness of 0.365 in., and a current wall thickness near 0.340 in. Nevertheless, it is still an unnecessary wall loss which will inevitably increase in its severity unless addressed.

With the insulation already removed, rehabilitation of the pipe can be accomplished by removing all heavier rust deposits using a wire wheel, applying a rust reverter to stop further deterioration, applying a top coat of a high solids waterproof paint, and then re-insulating. For chill water systems, 2 in. thick insulation is required. Our experience has shown that fiberglass insulation, the most common form of insulation applied in this area of the country, will inevitably fail - thereby allowing moisture to reach the pipe.

In terms of statistics, our investigation of 31 examples of chill water pipe identified a low and normal average corrosion rate of 0.5 mils per year (MPY), which we would consider very favorable. Testing in areas of the pipe having a smooth surface absent of any surface rust typically identified very high wall thickness at or just slightly below new pipe specifications to define very low internal corrosion activity.

We identified relatively minor surface rust randomly in some areas which, from the above example, can be shown to have had little significant impact against the pipe.

At left, a close-up photograph of the pipe surface better shows the moderate pitting into the pipe, and also that most of this heavier wall loss exists along the bottom. This defines that a long term condition of waterlogged insulation has existed for this pipe.

For areas of heavier rust, mild scraping was sufficient to allow accurate ultrasonic testing, where we identified very limited pitting. In the most heavily rusted areas brought to our attention, rust removal required the use of a motorized wire wheel to reveal noticeably deeper pitting but still favorable results. Although by visual inspection alone this chill water pipe may seem to be heavily deteriorated, external corrosion has not yet become aggressive enough to significantly impact the pipe.

Left to remain, however, we can reasonably speculate that such surface corrosion will accelerate now that it has been established. Re-insulation alone, without eliminating the existing outer threat, will only delay future deterioration of the chill water pipe as corrosion accelerates where pitting has already been established.

By rehabilitating this pipe through the application of an effective rust reverter and coating prior to re-insulation, this external corrosion threat will be eliminated entirely. Given that most wall loss to the chill water system has been identified externally, with very low internal corrosion, the elimination of this external threat will greatly extend the already favorable service life estimates in this report and allow it to provide almost unlimited service.

A good illustration to the threat posed by a continuation of this outer surface deterioration is provided by the results of location No. 29 at an example of smaller take-off line to the AHU units. Here, ultrasonic testing identified generally high wall thickness but also random areas of deep surface pitting. This is common to any tee or take-off line often lacking adequate insulation, or having breaks at the seams, thereby allowing moisture to easily infiltrate and damage the pipe.

At left we show a closer view of the take-off line at location No. 29 where deep surface pitting is evident having a depth of near 0.045 in. as measured by a surface depth micrometer. Lesser pitting was identified in most other areas of the chill water system in the range typically of near 0.035 in.

Such pitting represents the only threat to this chill water system; having a much greater impact at smaller diameter piping having inherently less wall thickness.

In terms of test results, a review of our measurements to all 31 examples of pipe in section four clearly shows a consistent result of high average wall thickness often not far below new schedule 40 specifications. In areas where testing was performed to pipe having no outer surface corrosion, measurements still identified some mild pitting activity which we would attribute to internal conditions. Such internal pitting activity would not be unexpected for an older closed piping system of this age where the sum total of all internal corrosion product likely still remains.

Stated earlier, any corrosion product typically remains within a closed piping system unless physically removed. It therefore carries the potential to produce higher under deposit pitting in any area of the system. Such deterioration is more common at long horizontal runs of pipe where particulates have the opportunity to settle out.

> **For that reason, we would strongly recommend the installation of a sidestream basket filtration unit or some other form of filtration to the chill water system in order to gradually remove three decades of iron oxide rust product.**

Even though corrosion activity would be considered low throughout this piping system, it still results in a significant volume of rust that now requires some corrective attention. The installation of sidestream filtration within the pump room, in addition to the application of an effective chemical dispersing agent to gradually remove and resuspend the fine rust particles back into solution for capture by the filter will produce a noticeable benefit to airport mechanical operations.

A first benefit is to remove particulates having the potential of reducing heat transfer efficiency throughout the piping system. A second benefit is to remove rust from the internal surface of the pipe where it both introduces higher under deposit corrosion as well as prevents anti-corrosion chemicals from effectively protecting the pipe.

Information related to sidestream filtration is provided in the appendix of the report. We also provide very useful information on the critically important proper installation of such units in the technical bulletins section of our Internet site: **www.corrview.com**

Testing throughout the larger diameter pipe produced very similar results showing still high average wall thickness far above any suggestion to a concern. Testing was also performed at the small diameter take-off lines to individual units where we also identified very favorable results although with lower service life estimates due to small diameter pipe. Corrosion activity was similar in most examples of small diameter take-off lines but with seemingly higher pitting activity. Since the examples of pipe we were able to address were welded rather than threaded, testing estimates still long service life in most examples. We identified lesser service life at location No. 29, which raises some concern, but better results in all other examples.

As a preventative and precautionary measure given the higher surface pitting at some examples of the take-off lines, and given that we were not able to address each and every example of such piping, any take-off pipe showing heavier surface rust should be considered for replacement. Any threaded take-off pipe originating at the chill water mains should be replaced.

Hot Water Heating - Locations 32 through 58

For any hot water heating system, there is no outer corrosion threat due to the higher temperature of the pipe. Minor surface corrosion will only occur during inactive summer months due to local humidity. For that reason, all measured wall loss and corrosion activity can be attributed to internal conditions exclusively.

Our testing of the hot water system produced noticeably higher corrosion and pitting activity in comparison to the chill water system, which is highly unusual and contrary to what had been expected. We identified a higher average corrosion rate of 0.8 mils per year (MPY) and also higher internal pitting. Beginning at location No. 32 we can show very obvious internal pitting activity common to most locations tested. A clear observation from our inspection is to the noticeably higher corrosion and pitting activity occurring to the supply side piping in comparison to the return side pipe.

For chill water systems, higher surface corrosion to the colder supply side pipe often results in a similar observation of greater deterioration at one side rather than the another. This condition, however, does not exist for hot water pipe were only internal corrosion activity is present.

A review of our test results consistently shows much higher corrosion activity at most supply piping locations. At location No. 44, for example, taken at the supply side pipe near pipe support # 13, testing identified a relatively high maximum corrosion rate of near 3 MPY and a lower service life estimate of 20 years. Testing at the adjacent return side main immediately below the supply main at location No. 45 identified less than half that corrosion rate, substantially less pitting, and a much more extended service life prediction of 100 years. This finding repeats itself throughout our investigation to suggest some internal condition responsible for this very significant difference in pipe condition.

With no further knowledge regarding the operation and maintenance of this hot water piping system, we can speculate that a combination of higher system wide corrosion activity and potentially inadequate flow rate has produced a condition where rust product created anywhere throughout the system lacks sufficient flow velocity to stay suspended. As a result, rust particulates are settling in the supply line to produce such higher corrosion and pitting activity.

> **Similar to our recommendation for the chill water system but of much greater importance, we would strongly suggest the installation of some form of side stream filtration to the hot water heating system in order to clean the system of what is likely a substantial amount of internal iron oxide rust product.**

We would also recommend an engineering review of flow conditions to this pipe in order to establish whether sufficient flow velocity exists. The very common *"green building"* interest today in energy conservation has resulted in the installation of variable speed circulation pumps and pump controllers which reduce water flow to low velocities insufficient to prevent particulate settlement along long horizontal runs. From a corrosion standpoint, lower flow rates traditionally increase corrosion activity. Installed into older closed systems where significant rust deposits already exist from decades of operation, such variable speed control systems will produce an unknown and unexpected result of higher corrosion and pitting activity to the piping. This is a very common corrosion scenario which we have documented in many past investigations. The use of variable speed pumping systems and lower flow rates, therefore, mandates a clean piping system.

Lacking any further information regarding this piping system or its operation, we can only suggest that low or inadequate flow within the hot water heating system may be a contributor to its current condition, and therefore recommend a review of current operating conditions. A critically important need for the system is to install sidestream filtration in addition to an effective chemical rust dispersing agent necessary to remove and re-suspend lighter iron oxide rust particulates from their current settled location.

A review of our test results for the hot water piping clearly shows a wider variation in conditions again based upon whether it is supply or return pipe. Testing at smaller diameter take-off lines identified the only immediate concern of this investigation due to much lower wall thickness measurements in this area. Shown beginning at location No. 54, we identified very similar corrosion and pitting activity to the larger main pipe. This pipe, however, is threaded, and therefore is under much greater threat due to initial wall loss in this area. In addition, brass isolation valves connected directly to carbon steel pipe introduce the potential of higher galvanic based corrosion at those same threads. While typically not of any concern where corrosion activity is very low, the direct connection of dissimilar metals, specifically brass to carbon steel, produces a dramatically greater impact as system wide corrosion and pitting activity increases.

We offer a close-up view of a current pinhole leak in the photo below.

While some results at this smaller take-off pipe are more favorable, the generally lower service life estimates produced, in addition to this obvious threat, suggests that it would be prudent to replace all such take-off pipe sections at this time.

We can suggest removing the existing welded lines to install new threatolets and then install heavier schedule 80 pipe nipples. The use of heavier schedule 80 pipe is strongly recommended due to the known higher corrosion activity which commonly occurs whenever a new pipe is installed into an older and more corroded piping system. For any threaded pipe installed into this hot water system, heavier schedule 80 material would be recommended.

Overall, this investigation produces generally good results showing both the hot and cold water piping systems in good to excellent condition and capable of providing still long service life. In comparison, the chill water system is in far better condition. We can caution the reader that simply re-insulating this pipe will not prevent further outer surface corrosion, and therefore the chill water piping must be rehabilitated through the application of a rust reverter followed by an overcoat and then re-insulation. A heavy outer vinyl or metal covering is always beneficial, but requires some form of silicone or mastic sealing at all its seams to be effective against moisture.

The hot water piping shows no such outer surface corrosion and therefore would not require similar protection prior to re-insulation. Both piping systems, however, require the addition of sidestream filtration in order to gradually clean them of internal rust deposits. The impact of such deposits, we believe, is best illustrated by the higher deterioration most obvious at the supply side hot water heating pipe, where we believe settlement is due to lower flow which in turn has produced a higher under deposit corrosion condition.

Specific Recommendations Related to the Findings of this Report

1. **Rehabilitate the chill water piping by removing all heavier rust deposits and coating the pipe with a rust reverter. Different product suppliers require different levels of surface preparation. Apply a final overcoat of a high solids waterproof paint, followed by heavy 2 in. thick insulation.**
2. **Install some form of filtration to both the chill water and hot water heating systems. For side stream filtration units, ensure their installation at the most effective locations.**
3. **Consult with the current chemical water treatment supplier for an effective but mild rust dispersing agent to be added to both piping systems.**
4. **Review current flow conditions to ensure that sufficient flow velocity exists to prevent particulate deposition.**
5. **Remove and replace the existing take-off lines to the hot water heating system. The use of heavier schedule 80 pipe is strongly recommended for any threaded applications.**
6. **Remove and replace the existing take-off lines to the chill water system where evidence of moderate or higher surface pitting exists, or where threaded.**

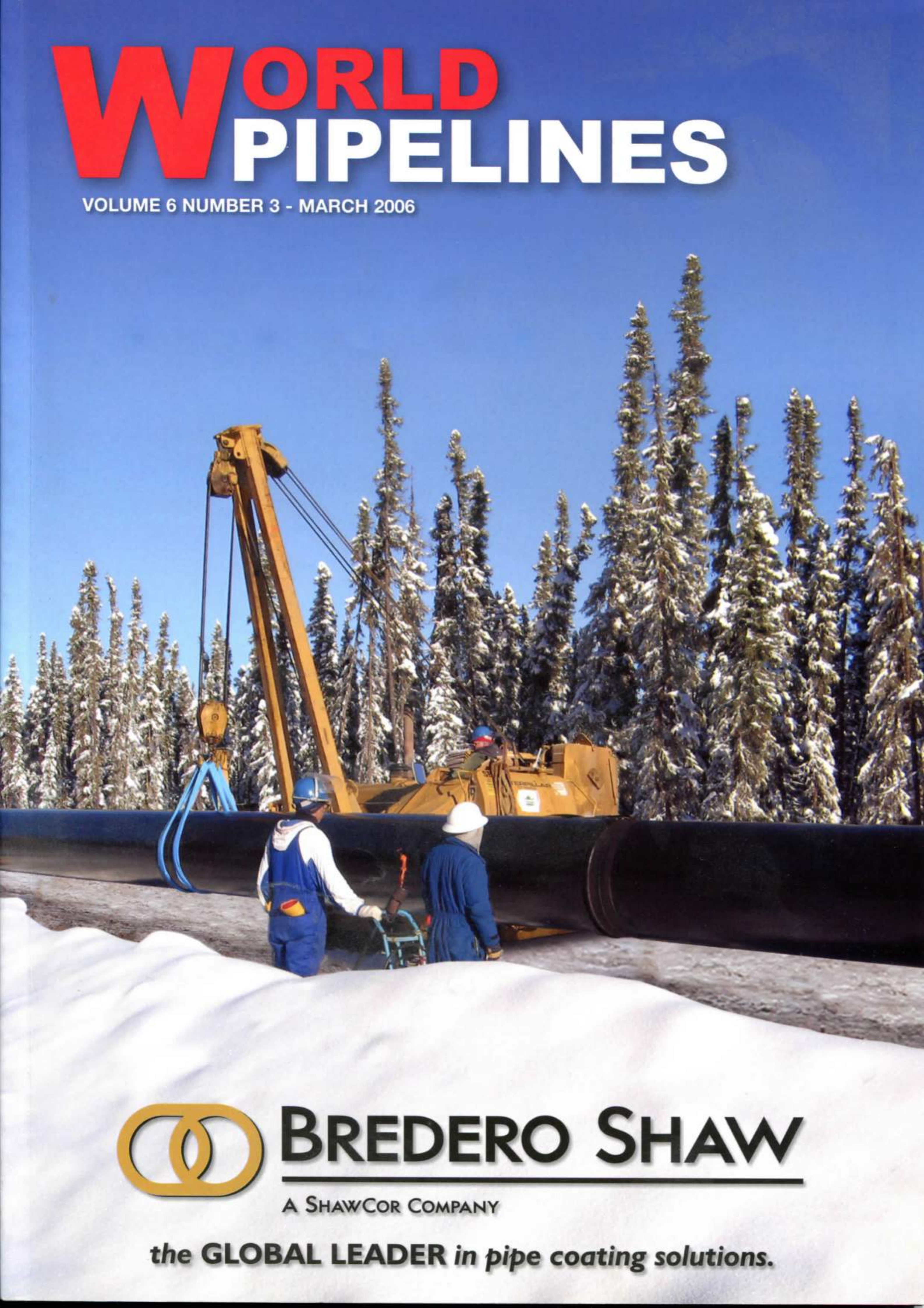
Raw Test Data from 38DL Plus For Locations 1-59

We offer below a table of all 708 individual wall thickness measurements taken during our investigation. 12 wall thickness measurements were recorded for each of the pipe test locations, which are represented in section four of this report by the top right bar graph. Presenting all 12 actual wall thickness measurements within each data page is not necessary, since the average and minimum thickness measurements are the critical values.

All individual values are represented here, with actual wall thickness measurements corresponding to the location number and grid number (A3, B3, C3 ...)

Location No:	A 3	B 3	C 3	A 6	B 6	C 6	A 9	B 9	C 9	A 12	B 12	C 12
1	0.369	0.365	0.363	0.359	0.363	0.320	0.339	0.364	0.363	0.367	0.361	0.360
2	0.359	0.355	0.351	0.352	0.310	0.336	0.354	0.349	0.356	0.357	0.363	0.350
3	0.350	0.350	0.347	0.333	0.346	0.352	0.353	0.352	0.347	0.357	0.355	0.334
4	0.353	0.359	0.354	0.352	0.356	0.349	0.352	0.359	0.356	0.340	0.356	0.349
5	0.361	0.365	0.366	0.361	0.367	0.325	0.354	0.343	0.362	0.360	0.358	0.357
6	0.360	0.367	0.329	0.359	0.356	0.362	0.358	0.356	0.335	0.361	0.361	0.364
7	0.365	0.361	0.364	0.361	0.374	0.357	0.321	0.348	0.347	0.365	0.349	0.362
8	0.365	0.328	0.360	0.361	0.359	0.356	0.358	0.364	0.359	0.357	0.365	0.363
9	0.358	0.364	0.355	0.354	0.313	0.332	0.360	0.355	0.357	0.353	0.359	0.359
10	0.363	0.366	0.361	0.359	0.346	0.360	0.329	0.359	0.364	0.365	0.352	0.353
11	0.356	0.360	0.356	0.356	0.360	0.354	0.360	0.360	0.336	0.314	0.340	0.365
12	0.363	0.330	0.349	0.360	0.359	0.359	0.365	0.362	0.357	0.361	0.359	0.355
13	0.360	0.357	0.354	0.356	0.355	0.319	0.336	0.359	0.361	0.360	0.356	0.335
14	0.360	0.355	0.327	0.311	0.356	0.351	0.359	0.359	0.360	0.353	0.355	0.357
15	0.357	0.353	0.369	0.352	0.350	0.355	0.309	0.333	0.356	0.357	0.354	0.355
16	0.364	0.362	0.357	0.357	0.361	0.359	0.353	0.355	0.365	0.342	0.326	0.365
17	0.320	0.316	0.301	0.309	0.310	0.307	0.310	0.315	0.296	0.275	0.319	0.308
18	0.310	0.319	0.313	0.310	0.317	0.321	0.313	0.297	0.287	0.311	0.309	0.319
19	0.310	0.310	0.314	0.321	0.317	0.292	0.268	0.314	0.315	0.315	0.310	0.315
20	0.313	0.314	0.283	0.297	0.315	0.314	0.319	0.315	0.321	0.316	0.317	0.315
21	0.314	0.307	0.316	0.310	0.320	0.314	0.297	0.314	0.300	0.284	0.315	0.309
22	0.315	0.303	0.319	0.314	0.279	0.293	0.317	0.311	0.310	0.310	0.311	0.320
23	0.314	0.310	0.319	0.312	0.282	0.270	0.309	0.311	0.314	0.312	0.312	0.299
24	0.311	0.315	0.309	0.277	0.295	0.312	0.308	0.314	0.307	0.320	0.315	0.308
25	0.316	0.300	0.312	0.315	0.309	0.283	0.298	0.307	0.318	0.308	0.306	0.313
26	0.315	0.307	0.309	0.305	0.307	0.313	0.313	0.313	0.313	0.306	0.319	0.306
27	0.218	0.209	0.224	0.217	0.212	0.222	0.208	0.196	0.186	0.219	0.219	0.212
28	0.205	0.199	0.192	0.206	0.191	0.191	0.198	0.192	0.190	0.178	0.200	0.196
29	0.197	0.191	0.196	0.204	0.152	0.133	0.190	0.199	0.192	0.191	0.186	0.190
30	0.187	0.180	0.185	0.184	0.181	0.178	0.183	0.164	0.145	0.184	0.201	0.185
31	0.189	0.154	0.166	0.180	0.180	0.175	0.189	0.184	0.188	0.179	0.179	0.188
32	0.273	0.261	0.264	0.270	0.243	0.238	0.219	0.273	0.251	0.263	0.255	0.257

Location No:	A 3	**B 3**	C 3	**A 6**	B 6	**C 6**	A 9	**B 9**	C 9	**A 12**	B 12	**C 12**
33	0.273	**0.261**	0.280	**0.275**	0.253	**0.242**	0.259	**0.268**	0.253	**0.276**	0.264	**0.239**
34	0.273	**0.228**	0.249	**0.238**	0.245	**0.263**	0.253	**0.228**	0.250	**0.218**	0.194	**0.207**
35	0.270	**0.261**	0.265	**0.245**	0.271	**0.253**	0.276	**0.274**	0.260	**0.259**	0.235	**0.248**
36	0.277	**0.256**	0.229	**0.243**	0.258	**0.246**	0.248	**0.278**	0.263	**0.228**	0.233	**0.258**
37	0.276	**0.264**	0.256	**0.264**	0.229	**0.265**	0.270	**0.257**	0.285	**0.272**	0.262	**0.256**
38	0.274	**0.264**	0.254	**0.232**	0.227	**0.254**	0.276	**0.262**	0.248	**0.262**	0.265	**0.259**
39	0.273	**0.266**	0.244	**0.254**	0.260	**0.277**	0.256	**0.284**	0.258	**0.268**	0.257	**0.250**
40	0.267	**0.243**	0.217	**0.258**	0.278	**0.254**	0.272	**0.209**	0.227	**0.253**	0.238	**0.227**
41	0.268	**0.252**	0.267	**0.273**	0.251	**0.242**	0.264	**0.279**	0.266	**0.263**	0.244	**0.264**
42	0.274	**0.253**	0.264	**0.247**	0.261	**0.246**	0.236	**0.262**	0.225	**0.215**	0.253	**0.236**
43	0.267	**0.264**	0.246	**0.264**	0.250	**0.265**	0.254	**0.238**	0.276	**0.264**	0.254	**0.251**
44	0.238	**0.209**	0.239	**0.267**	0.210	**0.246**	0.185	**0.231**	0.221	**0.216**	0.188	**0.236**
45	0.269	**0.281**	0.273	**0.273**	0.283	**0.255**	0.283	**0.265**	0.255	**0.243**	0.272	**0.266**
46	0.248	**0.217**	0.237	**0.250**	0.234	**0.249**	0.211	**0.236**	0.248	**0.217**	0.207	**0.235**
47	0.252	**0.256**	0.231	**0.258**	0.216	**0.235**	0.248	**0.223**	0.260	**0.257**	0.247	**0.239**
48	0.264	**0.241**	0.229	**0.250**	0.222	**0.209**	0.223	**0.218**	0.246	**0.194**	0.222	**0.246**
49	0.252	**0.243**	0.230	**0.226**	0.229	**0.249**	0.233	**0.228**	0.242	**0.247**	0.218	**0.219**
50	0.254	**0.230**	0.247	**0.224**	0.203	**0.199**	0.245	**0.217**	0.242	**0.236**	0.228	**0.214**
51	0.240	**0.221**	0.238	**0.248**	0.228	**0.251**	0.244	**0.252**	0.228	**0.232**	0.244	**0.244**
52	0.229	**0.258**	0.232	**0.229**	0.239	**0.220**	0.236	**0.248**	0.247	**0.235**	0.224	**0.244**
53	0.252	**0.229**	0.241	**0.237**	0.238	**0.244**	0.232	**0.225**	0.234	**0.226**	0.247	**0.231**
54	0.140	**0.110**	0.124	**0.128**	0.116	**0.127**	0.144	**0.133**	0.119	**0.136**	0.133	**0.123**
55	0.149	**0.135**	0.139	**0.138**	0.134	**0.135**	0.120	**0.134**	0.127	**0.136**	0.139	**0.135**
56	0.094	**0.101**	0.133	**0.125**	0.107	**0.116**	0.085	**0.090**	0.078	**0.133**	0.118	**0.096**
57	0.139	**0.121**	0.137	**0.127**	0.109	**0.135**	0.096	**0.129**	0.091	**0.102**	0.127	**0.124**
58	0.123	**0.115**	0.127	**0.132**	0.109	**0.129**	0.124	**0.119**	0.128	**0.115**	0.123	**0.128**
59	0.119	**0.116**	0.119	**0.137**	0.128	**0.119**	0.137	**0.124**	0.117	**0.140**	0.116	**0.120**



WORLD PIPELINES

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INVESTIGATION VS. PROCEDURE

William P. Duncan, CorrView International, LLC, USA, explains how the pipe testing process is vital in detecting and preventing corrosion based failure.

The enormous impact of a corrosion based failure to any piping system mandates various methods of testing be employed. Whether through ultrasound or other forms of nondestructive testing, the success and information gained from any investigative method is often as much dependent upon the locations selected for analysis, as the accuracy of the testing procedure itself.

For the very same reason that diagnostic testing is employed, that is to identify previously unknown conditions within a varying piping environment, any method of testing must also seek to address those areas potentially containing hidden corrosion threats.

Investigations not firmly bound by a pre-established testing protocol offer the advantage of focusing interest towards areas of pipe more likely to reveal a pending failure.

Beyond reassurance

A more effective testing and inspection programme, therefore, will approach the question of pipe corrosion/integrity more so as an ongoing investigation, than as a repetitive procedure. Efforts taken to annually confirm the same near specification wall thickness of a main service line will be better expended in testing a difficult to reach bottom drain, rarely utilised by-pass, or even downstream section of the same main line.

Pursued as an investigation, pipe testing will often evolve and expand into new areas of interest based upon prior results or speculation. As a repetitive NDT programme, however, it may remain fixated at only those test areas originally selected - all too often serving as simply a "feel good" reassurance of pipe quality.

A least beneficial form of pipe inspection programme is one in which test locations are selected based upon convenience and opportunity, or where simply fulfilling a testing requirement is the major concern. Ignoring certain areas of a piping system due to some difficulty in testing, whether it be due to physical access, field conditions, pipe temperatures, security, or insulation, etc., is often viewed in hindsight as the event allowing failure to occur.

System defines testing

An inherent limitation to any pipe testing programme is typically the expansive size of most piping systems - whether a petrochemical refinery, 60 story office building, or 700 mile trans-country oil pipeline. Establishing a baseline of pipe condition mandates some fixed or arbitrary testing interval initially, but once satisfied and showing acceptable conditions, should venture into secondary areas of interest.

Such secondary areas of investigation are primarily dependent upon the specific characteristics of the piping system itself - with pipe service, size, and location existing as the most important selection criteria. In many examples, potentially threatening characteristics

Figure 1. Heavy corrosion deposits along the length of a pipe. Severe pitting was found under the deposits.

Figure 2. This incidence of corrosion was detected by expanding testing into dead-end areas.

inherent to one piping system may not exist in another system otherwise similar. Therefore, a thorough understanding of each piping system, it is physical layout, operation, and historical vulnerability to corrosion become ever more important.

Variable threat exists

Corrosion varies between piping services, and often within different localised areas of the very same system. Its losses caused to the oil and gas industry are in the tens of billions of dollars worldwide, and rising.[1]

Where some piping may only be vulnerable to one form of potential loss, others may be attacked by corrosion on multiple fronts.

Process or cooling water systems, for example, typically suffer a greater corrosive loss than most oil or natural gas pipelines. A steam condensate return line will show far greater pitting activity than its steam supply counterpart. Cold region dry fire protection systems serving outdoor production areas will always show five or more times greater corrosion and pitting activity than identical indoor fire service piping having remained water filled.

While each piping system holds its own level of importance to any industrial plant or building operation, the heavily dependent interaction between most systems means that a minor failure at one may produce more broad and severe consequences elsewhere. The corrosion based failure of a fire protection line called into action will have occurred by definition at a time when a far greater emergency exists.

Variable protection afforded

The level of corrosion protection, whether in the form of internal chemical inhibitors or external coatings, is commonly related to the critical nature of the piping system in combination with recognised corrosion vulnerability. Corrosion monitoring is similarly dependent. Equal corrosion protection to different piping systems, much like equal integrity testing and monitoring, rarely exists.

Given the extreme corrosion threat to the exterior surface of any underground pipeline, strong countermeasures in the form of advanced protective coatings and cathodic protection are applied. Equal threat to outdoor process piping caused by water infiltration, moisture condensation, and insulation failure receives far less attention even though presenting similar potential to disrupt operations.

Unlike the typically effective insulation protection provided to large diameter main piping runs, insulation failures at its smallest fixtures such as gauges, sensors, injection points, and smaller take-off distribution lines will provide easy entry to water and moisture. Often hidden, just one such source of exposure can provide a starting point for corrosion under insulation to attack a wide area.

Sufficient history regarding various piping systems is generally available to provide some guidance toward investigating those more critical, but often overlooked, areas of potential threat.

Common corrosion concerns

A first step in the evaluation of any piping system is to anticipate potential problem areas. Small diameter pipe, and especially threaded pipe, are frequent points of failure. Wall thickness is inherently less as pipe diameter decreases, and can be reduced a further 50% after threading. A documented corrosion rate of 3 mils per year (MPY) acting against an interior pipe surface equally will much sooner breach a 2 in. schedule 40 threaded drain line having an available 0.069 in. wall thickness, than it's adjacent 24 in. main service line at 0.375 in.

Dead-end sections of pipe such as bottom drain lines are guaranteed traps for any particulates, thereby adding the threat of localised under deposit corrosion. For open cooling tower loops, such conditions provide the ideal environment for severely damaging microbiologically influenced corrosion (MIC) to develop.

Lead/lag or intermittently operated equipment such as heat exchangers, refrigeration chillers, and pumps are also susceptible to the accumulation of particulates - the underlying cause for many severe corrosion problems. For the same reason, a crossover line or valve by-pass will often show greater corrosion activity.

Cold water service piping can develop far more severe corrosion losses at its exterior than at its chemically treated interior - producing an unexpected two front corrosion attack. Moisture contained in oil and gas lines will focus higher corrosion activity along the bottom of the pipe and at low collection points.

Even the unethical substitution to thinner piping materials, surprisingly common, can transform the unimportance of a minor corrosion rate into a large scale piping weakness requiring immediate attention.

Pipe corrosion is universal and not discriminating; occurring wherever opportunity and a lack of prevention and/or monitoring exists. The below case histories, although not specifically related to the oil and gas industry, serve to illustrate corrosion events common to many piping systems, and a potential threat to almost any refinery or production plant.

Case history 1

A critical 24/7 refrigeration plant had previously shown low corrosion activity and excellent results through ultrasonic testing (UT) of its 24 in. condenser water piping. Repetitive annual UT testing in the same areas confirmed low 1 MPY corrosion rates and virtually unlimited service life. Follow-up testing, however, was focused on new areas of pipe suspected to contain potential problems.

Initial review of the plant operation revealed one such area being two 25 ft sets of 12 in. supply and return steel distribution lines to abandoned heat exchangers. With isolation valves installed at the heat exchangers rather than at the bottom connection to the main headers, and no flow, potential clearly existed for the collection of dirt and other particulates to produce an underdeposit corrosion scenario. Failure would be near catastrophic given no upstream means to isolate the lines.

Ultrasonic testing confirmed suspicion of this occurrence, and documented deep and severe pitting activity approaching the point of failure. The potential to shut down the entire facility and disrupt worldwide computer operations resulted in the emergency removal of all four lengths of pipe.

Shown in Figure 1, heavy corrosion deposits were found along the entire bottom length of the pipe. Severe pitting under the deposits confirmed UT predictions.

A major loss of service was therefore averted based upon speculation of an event having no outward indication nor prior history. Large scale failure would have occurred had not the regimented ultrasonic testing program been modified and a few minutes of testing effort invested.

Case history 2

A 37 story high rise office building experienced a heavy volume of particulates in its condenser water system; prompting ultrasonic pipe testing as a precautionary measure. Such testing addressed easily accessible roof level and mechanical room piping, but ignored the small diameter connections and the generally inaccessible vertical main risers.

Given the prior finding of a moderate 3 - 4 MPY corrosion rate and the known presence of iron oxide to the system, greatest threat was anticipated at any dead-end areas whereby such particulates might accumulate to produce more severe underdeposit corrosion.

Expanding prior testing efforts by demanding access into the shaftway and to multiple 1 in. abandoned valve connections produced the finding shown by Figure 2.

Particulates filling the small 1 in. threaded connection fully clogged the outlet. Its small diameter steel nipple then corroded through completely and separated due to a combination of severe under deposit corrosion, galvanic activity between the brass valve and carbon steel pipe, and localised stresses.

Pending failure was also found at the adjacent supply riser connection and in other areas of a piping system required to provided uninterrupted 24/7 critical cooling service. Approximately 15 floors of 24 in. condenser return water pipe to the roof existed above this point, with 150 psi of water pressure amazingly held back by only the presence of some rust product.

With no possible means for shutdown after its failure, disaster in the form of a major flood and building shutdown was inevitable, and would have occurred had the interest to specifically seek out such potential threat not been pursued.

Targeted problem areas

As the complexity of any piping system increases, so does the potential for a far greater variety of corrosion problems to develop. A refinery or processing plant will contain a massive volume of independent piping systems each carrying with it individual corrosion characteristics, varying levels of protection, and multiple opportunities for different levels of corrosion to occur.

High priority areas to address are typically:

- Small diameter piping.
- Threaded lines and fittings.
- Dead-end zones.
- Frequently drained pipe.
- By-pass lines.
- Bottom pipe areas.
- Insulated pipe.
- Dry fire piping.
- Unprotected piping.
- Bottom drain lines.
- Airbound lines.
- Top vent lines.
- Lowest areas of the system.
- Cold piping services.
- Small insulated fixtures.

Conclusion

The severe consequences existing today as a result of any piping failure demand added reassurance of pipe condition through more thorough testing procedures. Although the benefit of any pipe testing program is always related to the volume of areas evaluated, or more precisely the number of test points taken, the selection of those test points is often an even more important consideration.

The ultimate benefits of any such testing effort can be significantly improved by identifying potential threats, speculating others, and then expanding available diagnostic resources into those areas.

References

1. http://www.corrosioncost.com

Canaan Preventative Master Maintenance Plan

Unit	Room Number	Type	Serves	Action	Daily	Weekly	Monthly	Quarterly	Semi Annually	Annually	3 Years	Information
SFC		El Heat/DX Cool	Hallway	Check Operation/ Disch Temps		X						Set controls to heating and cooling and verify proper operations in both modes
				Visual Check Cond Unit/ Noises?		X						
SFC-1	114			Change Filters			X					
SFC-2	144			Check Belt condition/ tension			X					Does it squeek on start?
SFC-3	165			Grease Bearings - 1 stroke			X					(Wipe away excess)
SFC-4	C41A			Check Refrigeration sight glass for bubbles/moisture			X					
SFC-5	C42A			Clean Interior of unit intake/filter section				X				
SFC-6	Z124			Check Condensing unit fan for vibration and speed				X				Does fan start quickly?
SFC-7	171			Clean DX coil on indoor unit					X			Use Calgon HD and water, rinse fully. Do not use pressure washer
				Clean Condensing Unit Coil					X			Use Calgon HD and water, rinse fully. Do not use pressure washer
				Hand ck airflow at all diffusers and grilles on system					X			
				Check Indoor unit blower motor amps and record						X		
				Check Indoor unit heating amps and record						X		Perform at full call for heating
				Check outdoor unit fan motor amps and record						X		
				Check outdoor unit compressor amps and record						X		Perform at full call for cooling
				Check wear on indoor unit blower sheeves						X		
				Check condition of indoor unit blower bearings						X		
				Check airflows with hood against Balance report							X	Investigate deviations of more than 5%
VAV Box		Fan Powered	Varies	Verify Space served is holding temp			X					
				Hand check for airflow/ VAV Fan operation			X					
FPB-1-1	Z123			Change Filters in return of box				X				
FPB-1-2	100			Check Airflow Operation of Box				X				Adjust setpoint to drive box open in cooling, then heating, hand check volume
FPB-1-3	162			Check Operation of reheat coil				X				Adjust setpoint to call for full heating then ck disch temp
FPB-1-4	161			Vaccuum Reheat coil							X	
FPB-1-5	174											
TB-2-1	261											
TB-2-2	265											
TB-2-3	260											
TB-2-4	265											
TB-2-5	Mezzanine South											
TB-2-6	Mezzanine South											
TB-2-7	Mezzanine South											
TB-2-8	Mezzanine South											
TB-2-9	Mezzanine South											
FPB-2-10	x214											
Exhaust Fans				Check Operation/ hand check grilles for airflow			X					
				Visual Check Unit/ noises?			X					
EF-1	104			Check Belt condition/ tension			X					

EF-2	134			Grease Fan Bearings - 1 stroke			X					Use lubricants found on page 6 of IOM Manual (Wipe away excess)
EF-3	204			Oil Motor bearing				X				Use lubricants found on page 6 of IOM Manual (Wipe away excess)
EF-4	234			Check Fan bearing wear					X			
EF-5	304			Clean exhaust grilles					X			
EF-6	334			Clean Fan housing					X			
EF-7	404			Check fan motor amps and record						X		Compare to previous year
EF-8	434			Change Belt						X		
EF-9	Mezzanine North			Visual and hand check ductwork for leaks						X		
EF-10	Mezzanine North			Check airflows with hood against Balance report							X	
AHU				Check Operation/ Disch Temps		X						Log in unit specific logbook
				Visually check for leaks, drips		X						
				Change Filters			X					Log date of change in logbook, ensure filters fit properly and any fill plates are re-installed. Shut unit down during filter change. Vacuum filter housing while filter are out.
AHU-10	158			Check Belt condition/ tension			X					
AHU-11	160			Grease Bearings - 1 stroke			X					
AHU-12	158			Put tabs in condensate pans			X					
AHU-13	161			Check operation of HW /CW valves			X					
				Check operation of mixing section dampers			X					
				Clean Interior of unit intake/filter section				X				
				Check blower fan for vibration and noise				X				
				Hand check airflow at all diffusers and grilles				X				
				Clean Heating and cooling coils				X				Check in late August for proper operation
				Clean Condensate Pan and check for proper flow				X				
				Clean and lubricate mixing section damper linkages and bearings				X				Use approved dry lubricant, no oil, no oil based sprays
				Cycle HW/CW isolation valves open/closed 3 times					X			
				Check and record testing of duct detectors				X				Check both supply and return detectors, if so equipped
				Check outdoor unit fan motor amps and record						X		Check supply and return fan motors, if so equipped
				Check outdoor unit compressor amps and record						X		
				Check wear on unit blower sheeves						X		
				Check condition of indoor unit blower bearings						X		
				Replace belt(s)						X		
				Check system airflow with hood and compare to TAB report values							X	
Pumps		Base Mounted Pumps		Visually check for leaks, change in sound		X						
				Check temps, suction and discharge pressures, log		X						
P-3	158			Grease bearings - 1 stroke			X					
P-4	158			Check condition of pump/ motor coupling			X					
P-5	158			Check Oil sump if so equipped			X					
P-6	158			Shut off pump and cycle isolation valves open/closed 3 times					X			
P-7	158			If VFD equipped, cycle speed on BAS and verify pumps slow					X			

P-8	158			Check motor starter or VFD overcurrent protection						X		
				Check motor amps and record						X		If VFD, must use TRUE RMS Ammeter
				Remove and inspect strainer						X		
				Remove gauges and test them with low pressure air for operation						X		Gauge should read zero when exposed to atmosphere, must remove to check
				Check and record motor amps and pressures and compare to TAB report							X	
				Change rubber insert in pump/ motor coupling							X	
Pumps		Inline Circulator Pumps		Visually check for leaks, change in sound		X						
				Check temps, suction and discharge pressures, log		X						
P-1	158			Check Oil sump if so equipped			X					
P-2	158			Shut off pump and cycle isolation valves open/closed 3 times					X			
				Check motor starter overcurrent protection						X		
				Check motor amps and record						X		
				Remove gauges and test with air for operation						X		
				Check and record motor amps and pressures and compare to TAB report							X	If VFD, must use TRUE RMS Ammeter
				Change motor coupling for condition and alignment							X	
Boiler		Condensing Boilers	Heating	Check Boiler Room clear of debris, dirt, combustibles	X							Pay Particular attention to combustibles in space - Log in Notebook left in boiler room
				Once each Shift, log temperature and pressure from temp/pressure gauge	X							Log in Notebook left in boiler room
B-1	158			Check Venting and Air Inlet piping for integrity, along its entire length			X					Use roof safety practices
B-2	158			Check Screens on Vent and Inlet on roof for obstructions			X					Use roof safety practices
				Inspect the relief valve and relief valve pipe for signs of weeping or leakage			X					If valve often weeps, contact service technician, expansion tanks may be faulty
				Check Condensate drain systems			X					Inspect the boiler condensate drain, vent line, fittings, and trap for flow, blockage, and damage
				Flush Condensate Trap with water				X				See procedure on page 54 of Installation & Operation manual
				Test low water cutoff					X			See Manufacturers instructions, reset by hitting button to re-fire boiler
				Check Boiler gas and water piping for leaks					X			Check gas using bubbles or leak detector, ck supply piping and gas train while firing (if unsure have gas train checked by service tech)
				Operate relief valve to ensure it is not corroded or blocked						X		Visually verify flow from relief drain
				Annual Tune Up						X		Have boiler services and adjusted, including combustion analysis, by factory trained service tech utilizing pages 54-57 of the Installation & Operation Manual as the requirement for the work. Follow recommendations to replace any wear parts, perform this is late August.
				Third party inspection of relief valve							X	Inspect Relief Valve
Condensing Units/Heat Pum		Small and Large	Various	Check General Operation		X						Check weekly in season for general proper operation
				Check Refrigeration sight glass for bubbles/moisture			X					